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Ducks Unlimited, Inc.

Ducks Unlimited, Canada

December 2009

Stikine River and Delta Land Cover Classification

Partners
The USDA – U.S. Forest Service; Ducks Unlimited, Inc.; and Ducks Unlimited, Canada completed this project under a Challenge Cost Share Agreement.

Cover
The cover photo depicts the coastal marshes and tidal flats of Sergief Island in the Stikine River Delta.

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Stikine River and Delta
Land Cover Classification
- Final Report -

December 2009

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Introduction

Executive Summary

This project produced a high quality digital earth cover database for the Stikine River area of Alaska and Canada. More specifically, the project field verified, and classified Landsat satellite imagery to produce high quality, moderate resolution digital resource base maps of dominant land cover types in the Stikine River and Delta area. Land cover information was gathered using helicopter or boat access to 231 field sites between August 21 and August 26, 2007. Thirty-three land cover classes were mapped in a 152,000 hectare project area. The result of this project is an integrated GIS database of georeferenced field site data, digital photos and a land cover data layer that can be used for improved natural resources planning.

Background

The Stikine River provides critical waterfowl and shorebird habitat in the Interior Passage region of southeastern Alaska's Pacific Coast. The freshwater and tidal wetlands along the river's floodplain and delta provide breeding habitat and migration habitat for numerous waterbird species. Following the Yukon-Kuskokwim Delta and the Copper River Delta, the Stikine is the next most important staging habitat for migrating snow geese populations along the Pacific Coast, particularly for the Wrangell Island snow goose population. Additionally, the wetlands along the lower floodplain of the Stikine extend across the U.S. - Canadian border, making this an area of international significance. Understanding the extent and distribution of critical wetland habitats in this area is crucial to maintaining suitable breeding and migratory staging habitats for waterbirds on the Pacific Coast.

In 1988 Ducks Unlimited, Inc. (DU) and the Bureau of Land Management (BLM) – Alaska began cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and OTS technologies (Ritter et al. 1989). The initial mapping projects that were undertaken focused on mapping only the wetland types such as deep marsh, shallow marsh, and aquatic classes (Rittter et al, 1989). It soon became apparent that mapping the entire landscape was more cost effective and useful to both managers and habitat studies. Over the years, many refinements have been made to both the techniques of collecting field information and classifying the imagery. Throughout that time period, DU has cooperated with many other agencies in Alaska including the U.S. Forest Service, National Park Service, U.S. Fish and Wildlife Service, Alaska Department of Natural Resources, North Slope Bureau, and Alaska Department of Fish and Game to map earth cover for over 60 million hectares throughout the State. A satellite inventory of earth cover serves many purposes. It provides baseline acreage statistics and corresponding maps for areas that currently lack or have outdated information for decision making. It is very useful for planning. Environmental Impact Statements (EIS), Comprehensive Management Plans (CMP) and other regional studies that are mandated by Federal Government. It can be integrated with other digital data sets into a GIS to produce maps, species of interest and can guide biologically driven decisions on land use practices (Kempka et al. 1993). Knowledge of the size, shape, distribution and extent of earth cover types, when linked to species habitat and human activities vastly improve decision-making capabilities.

Project Location

This project produced a landcover map for approximately 40 miles of the lower Stikine River stretching from the river's mouth upstream just past the confluence of the Iskut River in Canada (Figure 1). The entire project boundary encompasses an area of approximately 172,000 hectares. However, only areas below the 2000' contour line were mapped due to restrictions in the helicopter safety plan developed for the fieldwork portion of the project. The mapped area totaled approximately 152,000 hectares.

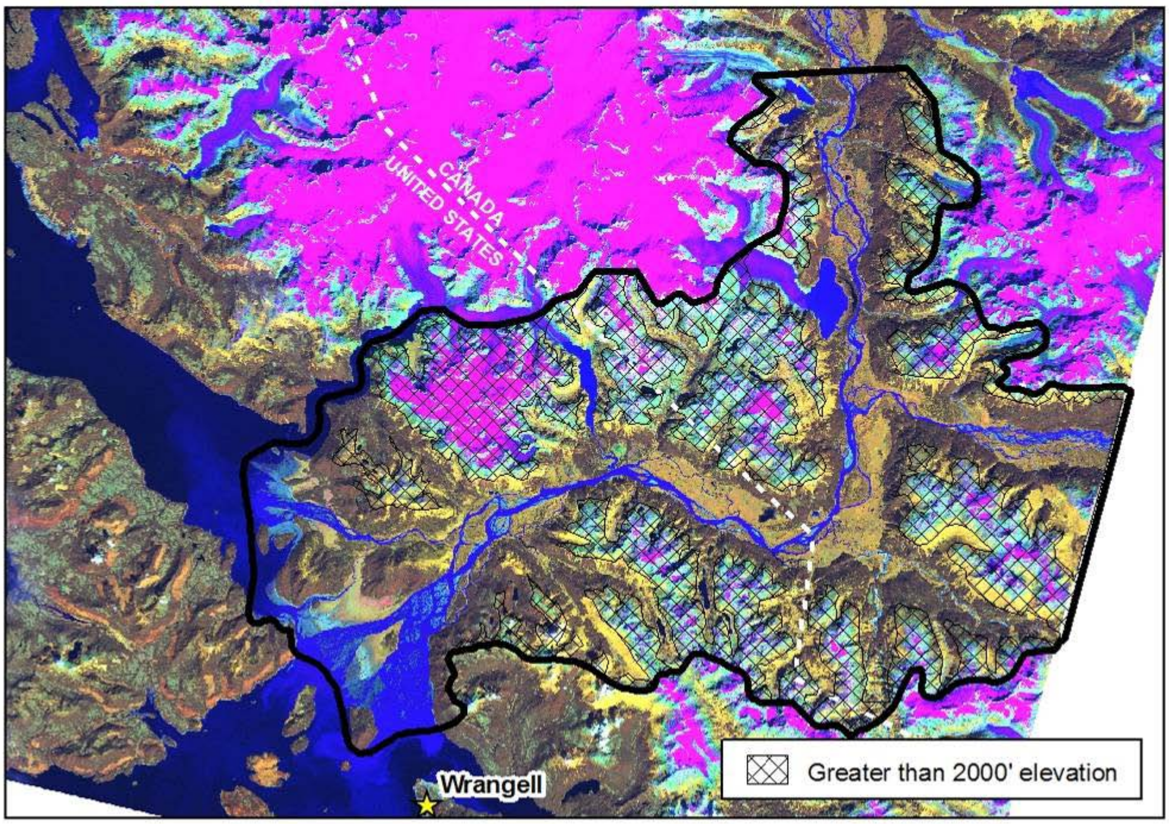


Figure 1. Boundary of Stikine River and Delta Land Cover Mapping Project.

Data Acquisition

A single Landsat Enhanced Thematic Mapper (TM) Image for Path 56 Row 20, acquired August 12, 1999, was provided by the US Forest Service Tongass National Forest for use in mapping the project area. Field work was conducted from August 21 through August 26, 2007. Field sites were visited by boat access on August 21 and August 22. This provided the field crew an on-the-ground view of several field sites and allowed them to familiarize themselves with vegetation species within the various land cover types. Field sites were accessed by helicopter on August 23 - 26.

Other ancillary data used in this project included: scanned digital true color resource photography provided by the USFS Tongass NF and USGS Digital Elevation Models (DEM).

Methods

Classification Scheme

The classification system utilized for the project was based on Ecological Systems of Alaska (NatureServe 2008). In some instances, due to the relative inability to discriminate between vegetation classes within the Landsat TM imagery, the classes in this ecological systems classification were generalized or grouped into broader classes. In other instances, multiple spectral classes were defined within one general class from the ecological system classification when multiple, distinct, visual breaks were evident in the Landsat imagery. A full description of each land cover class mapped and example photos for each type are included in Appendix A.

It should be noted that at the onset of the project there was no classification scheme defined for the project area. It was the US Forest Service's desire to utilize a classification scheme that was developed using National Vegetation Classification System (NVCS) standards. However, this work had not been completed for the Stikine area and would not be complete during the time frame that funding was available to perform this mapping project. During field data collection, field sites were labeled using a classification scheme derived from Viereck (1992). Upon returning from the field data collection it was decided to use a classification scheme based on the Ecological Systems of Alaska (NatureServe 2008) recently developed and utilized during the USGS' LANDFIRE project within Alaska. The vegetation species information and digital photos in the field site database were reviewed and sites were relabeled using the Ecological Systems class labels.

Image preprocessing

The image was examined for quality and consistency. Each band was examined visually and statistically by reviewing histograms. Combinations of bands were displayed to check for band-to-band registration and for clouds, shadows, and haze. Positional accuracy was checked by comparing the image to available ancillary data such as adjacent imagery, hydrography, and DEM's. Although the image was generally well georeferenced, there were inconsistencies in the alignment with the DEM data layer. Slope, aspect, and shaded relief layers did not consistently align with the TM image along ridge tops nor at the bases of hillsides and mountainsides along the river floodplain. These inconsistencies limited the utility of the DEM layer as a tool for identifying and correcting errors within the classified map.

Image pre-processing also included the selection of sites to be visited during the field verification portion of the project. To optimize helicopter efficiency, field sites were identified and plotted on field maps before fieldwork began. Sufficient samples were selected to span the variation of spectral responses within individual land cover classes and throughout the entire image. For example, a shrub class in the southern part of the image may have a different spectral response than the same shrub class in the northern part of that image. Many factors contribute to such variation, including aspect, terrain shadow, or small differences in soil moisture. In addition, most land cover types encompass a variety of subtypes; e.g., the sitka spruce class included forested areas with 25%-100% crown closure, trees of varying height, and a diverse understory composition.

An unsupervised classification was used to identify spectrally unique areas within the study area. The image analyst individually selected training sites from these spectrally unique areas using image objects (polygons) created within Definiens Developer software. The image objects were intersected with the unsupervised classification and these were then evaluated to identify objects having consistent spectral signatures. Image objects that consisted of at least 75% pixels of one class and had standard deviations of 3.0 or less in all six spectral bands were chosen as potential objects to be visited in the field. A subsample of at least 30 of these image objects were then chosen for each unsupervised class and plotted on the field maps. Whenever possible, training sites were grouped in clusters to reduce the amount of travel time between sites. The image analyst also to placed training sites near landmarks that were easily recognizable in the field, such as lakes or streams. The coordinates of the center points of the field sites were then uploaded into a Garmin GPSMap60s for navigational purposes. Training sites were overlain with the satellite imagery and plotted at 1 inch = 1 mile scale. Additionally, 1-mile buffer zones were plotted on the field maps around locations of known cabins within the project area. No field sites were visited within these areas to minimize disturbance to recreationalists and locals with property inholdings within the project area. These field maps were used for recording field notes, placing additional field sample sites, and navigating to field sites.

Field Verification

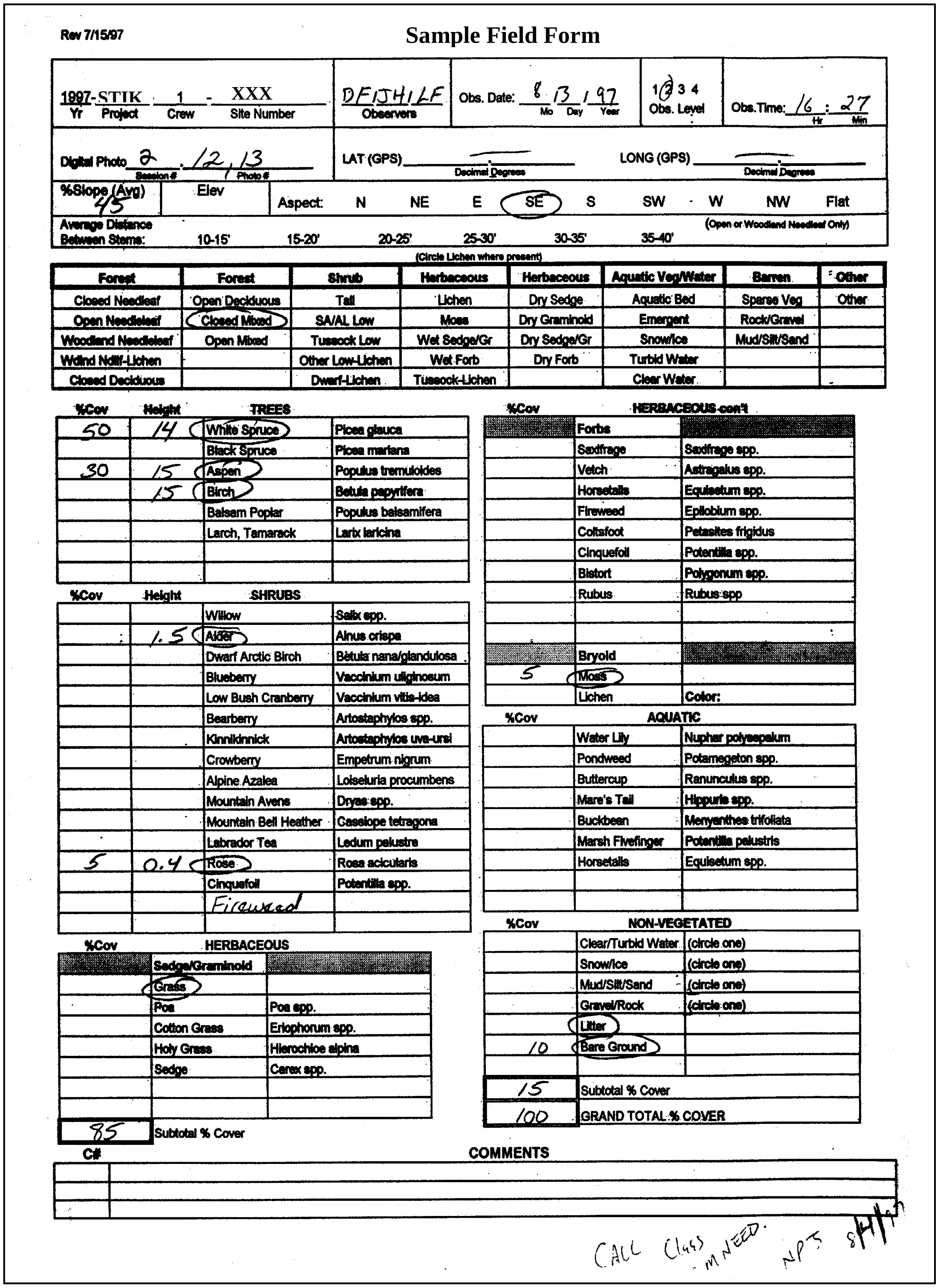
The purpose of field data collection was to assess, measure, and document the on-the-ground vegetation variation within the project area. This variation was correlated with the spectral variation in the satellite imagery during the image classification process. Low-level helicopter surveys were a very effective method of field data collection since a much broader area was covered with an orthogonal view from above, similar to a satellite sensor. Aerial surveys are the only alternative for gathering an adequate number of field sites within a project area of this size when there is no road access. A special use permit was acquired and detailed helicopter safety plan was developed by USFS staff for the use of helicopter surveys within the Stikine Wilderness Area. As part of the plan, the helicopter was not allowed to land within any portion of the project area. An “A-star” helicopter based from the Wrangell, AK airport was used to access the field sites. A jet boat based from Wrangell was utilized to access ground visited field sites during the first two days of field work.

To obtain a reliable and consistent field sample, a custom field data collection form was developed and used to record field information (Figure 2). A four person helicopter crew performed the field assessment. The crew consisted of a pilot, biologist/ecologist, navigator, and helicopter manager. The navigator operated the GPS equipment and interpreted the satellite image derived field maps to guide the pilot to the pre-defined field site and took digital photographs of all sites. It was valuable for the image processor to gain first-hand knowledge of the project area, so therefore the image processor had the navigator role. The biologist identified plant species, estimated the percent cover of each cover type, and determined the overall land cover class. The helicopter manager observed all flight activities and verified that all portions of the helicopter safety plan were being followed.

These procedures for collecting field data have been utilized by DU and partners to gather field data for land cover mapping projects throughout Alaska over the past 15 years and have evolved into a very efficient and effective means of data collection. The navigator used a GPS to locate the site and verified the location on the field map. As the helicopter approached the site at about 300 meters above ground level the navigator described the site and the biologist took a picture with a digital camera. The pilot then descended to approximately 5-10 meters above the vegetation and laterally moved across the site while the biologist recorded the vegetation information on the field form. The navigator took additional pictures with the digital camera for a close-up view of the site. The pilot then ascended to approximately 100 meters so that the biologist could estimate the percentages of each species. The navigator then directed the pilot to the next site. On average, it took approximately 4-6 minutes to collect all of the information for one site.

Field Data Analysis

The collected field information was entered into a digital database using a custom data entry application (DUFF – Ducks Unlimited Field Form). The user interface was organized similarly to the field form to facilitate data entry (Figure 3). The application utilized pull down menus to minimize keystrokes and checked for data integrity to minimize data entry errors. The database program also calculated an overall class name for each site based on the recorded species and its cover percentage. Digital images from each site were stored in the database and accessible from within the user interface. The number of field sites per earth cover class was tracked daily to ensure that adequate samples were being obtained within each class.



Rev 7/15/97

Sample Field Form

1997-STIK 1 - XXX (Yr, Project, Crew, Site Number)	DF/JH/LF (Observers)	Obs. Date: 8/13/97 (Mo, Day, Year)	1 ② 3 4 Obs. Level	Obs.Time: 16 : 27 (Hr, Min)
Digital Photo 2 . 12, 13 (Session #, Photo #)	LAT (GPS) ___ . ___ (Decimal Degrees)		LONG (GPS) ___ . ___ (Decimal Degrees)	

%Slope (Avg) 45 | Elev | Aspect: N NE E (SE) S SW W NW Flat

Average Distance Between Stems: 10-15' 15-20' 20-25' 25-30' 30-35' 35-40' (Open or Woodland Needleleaf Only)

(Circle Lichen where present)

Forest	Forest	Shrub	Herbaceous	Herbaceous	Aquatic Veg/Water	Barren	Other
Closed Needleaf	Open Deciduous	Tall	Lichen	Dry Sedge	Aquatic Bed	Sparse Veg	Other
Open Needleleaf	(Closed Mixed)	SA/AL Low	Moss	Dry Graminoid	Emergent	Rock/Gravel	
Woodland Needleleaf	Open Mixed	Tussock Low	Wet Sedge/Gr	Dry Sedge/Gr	Snow/Ice	Mud/Silt/Sand	
Wdlnd Ndlf-Lichen		Other Low-Lichen	Wet Forb	Dry Forb	Turbid Water		
Closed Deciduous		Dwarf-Lichen	Tussock-Lichen		Clear Water		

TREES

%Cov	Height	TREES	
50	14	(White Spruce)	Picea glauca
		Black Spruce	Picea mariana
30	15	(Aspen)	Populus tremuloides
	15	(Birch)	Betula papyrifera
		Balsam Poplar	Populus balsamifera
		Larch, Tamarack	Larix laricina

SHRUBS

%Cov	Height	SHRUBS	
		Willow	Salix spp.
	1.5	(Alder)	Alnus crispa
		Dwarf Arctic Birch	Betula nana/glandulosa
		Blueberry	Vaccinium uliginosum
		Low Bush Cranberry	Vaccinium vitis-idea
		Bearberry	Artostaphylos spp.
		Kinnikinnick	Artostaphylos uva-ursi
		Crowberry	Empetrum nigrum
		Alpine Azalea	Loiseluria procumbens
		Mountain Avens	Dryas spp.
		Mountain Bell Heather	Cassiope tetragona
		Labrador Tea	Ledum palustre
5	0.4	(Rose)	Rosa acicularis
		Cinquefoil	Potentilla spp.
		Fireweed	

HERBACEOUS

%Cov	HERBACEOUS	
	Sedge/Graminoid	
	(Grass)	
	Poa	Poa spp.
	Cotton Grass	Eriophorum spp.
	Holy Grass	Hierochloe alpina
	Sedge	Carex spp.
85	Subtotal % Cover	

HERBACEOUS con't

%Cov	HERBACEOUS con't	
	Forbs	
	Saxifrage	Saxifrage spp.
	Vetch	Astragalus spp.
	Horsetails	Equisetum spp.
	Fireweed	Epilobium spp.
	Coltsfoot	Petasites frigidus
	Cinquefoil	Potentilla spp.
	Bistort	Polygonum spp.
	Rubus	Rubus spp
	Bryoid	
5	(Moss)	
	Lichen	Color:

AQUATIC

%Cov	AQUATIC	
	Water Lily	Nuphar polysepalum
	Pondweed	Potamogeton spp.
	Buttercup	Ranunculus spp.
	Mare's Tail	Hippuris spp.
	Buckbean	Menyanthes trifoliata
	Marsh Fivefinger	Potentilla palustris
	Horsetails	Equisetum spp.

NON-VEGETATED

%Cov	NON-VEGETATED	
	Clear/Turbid Water	(circle one)
	Snow/Ice	(circle one)
	Mud/Silt/Sand	(circle one)
	Gravel/Rock	(circle one)
	(Litter)	
10	(Bare Ground)	
15	Subtotal % Cover	
100	GRAND TOTAL % COVER	

C#	COMMENTS

CALL Class, in NEED. NPS 8/4/97

Figure 2. Custom field data collection form.

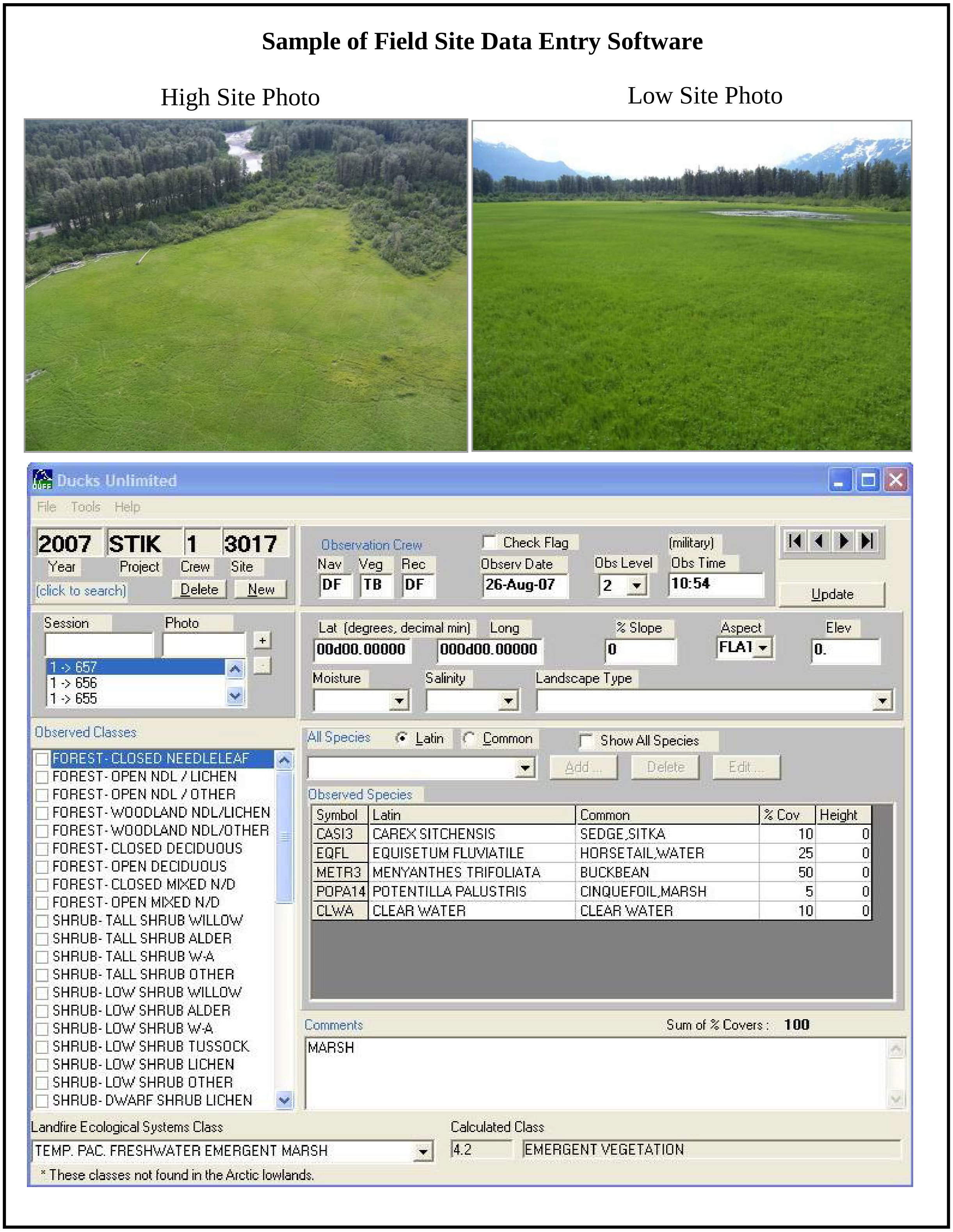


Figure 3. The customized database and user interface for field data entry (DUFF).

Classification

Every image is unique and presents special problems in the classification process. The combined supervised/unsupervised approach used in this project (Figure 4) has been proven successful over many years. The image processor was actively involved in the field data collection and had first-hand knowledge of every training site. The image processor's site-specific experience and knowledge of the ecology of the cover types helps overcome problems where spectral confusion exists between land cover classes and aids in producing a high quality, useful product.

Erdas Imagine (vers. 9.3) was used to perform the classification. ESRI ArcGIS (vers. 9.3) was utilized to manage the field site polygons. At the onset of the project, Definiens Developer software was used to perform some of the initial processing of the imagery. However, the Definiens software had difficulty segmenting and classifying nearly one quarter of a TM scene as one unit. Image objects needed to be larger and more generalized, or the project area had to be tiled and classified in multiple sections in order to continue using the Definiens software. At that point it was decided to utilize traditional pixel based classification methods for the remainder of the project.

Generation of New Bands

The Landsat TM imagery contained 7 bands of data: 3 visible bands, 1 near-infrared band, 2 mid-infrared bands, and 1 thermal band. Four derived bands were generated and used within various iterations of the unsupervised classifications that were run for this project. One new band was created using a band-4/band-3 ratio, a band ratio that typically reduces the effect of shadows in the image and enhances the differences between vegetation types (Kempka et al. 1995, Congalton et al. 1993). Additionally, a Tasseled Cap transformation was run and the brightness, greenness, and wetness bands were inserted into a few of the unsupervised iterations. In most instances, these derived bands did not greatly improve the separation between classes over the original 6-band TM image, and the majority of the map was produced using only the original six bands only.

Removal of Clouds and Shadows

Clouds and cloud shadows covered a very minor portion of the project area, and were simply removed using unsupervised classifications and on-screen digitizing to discern cloud shadows from other dark regions in the image.

Generation of Unsupervised Signatures

Unsupervised classifications were generated in all iterations of the classification process. The unsupervised spectral signatures were generated using the ISODATA algorithm within Erdas Imagine's unsupervised classification tool. Maximum likelihood classifications of the unsupervised signatures were generated using the supervised classification tool within Imagine.

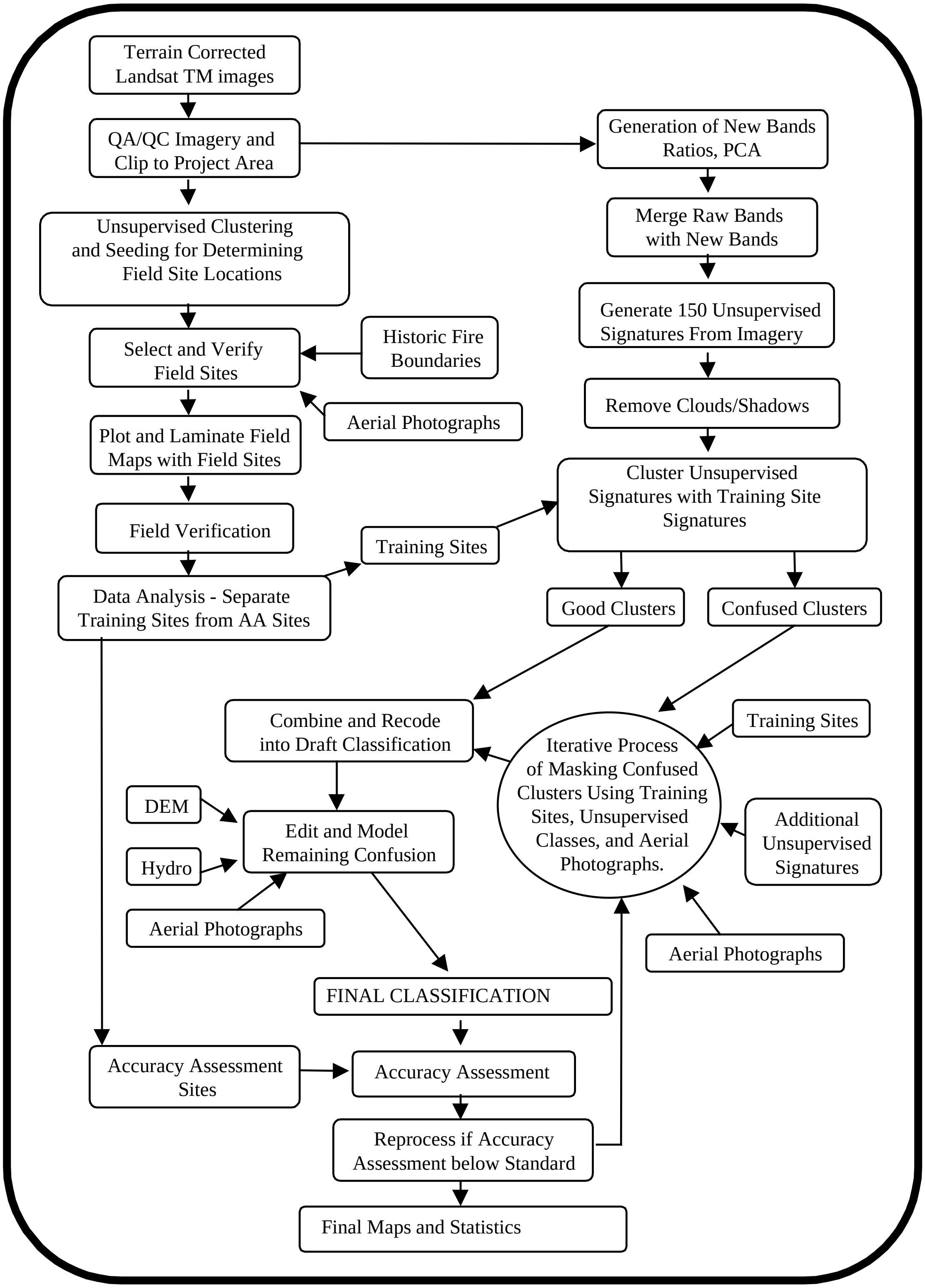


Figure 4. Image processing flow diagram.

Modified Supervised/Unsupervised Classification

A modified supervised/unsupervised classification approach (Chuvieco and Congalton 1988) was used for the classification. This approach used a statistical program to group the spectrally unique signatures from the unsupervised classification with the signatures of the supervised training areas. In this way, the spectrally unique areas were labeled according to the supervised training areas. This classification approach provided three major benefits: (1) it aided in the labeling of the unsupervised classes by grouping them with known supervised training sites; (2) it helped to identify classes that possessed no spectral uniqueness (i.e., training sites that were spectrally inseparable); and (3) it identified areas of spectral reflectance present in the imagery that had not been represented by a training site. This approach was an iterative process because all of the supervised signatures do not cluster perfectly with the unsupervised signatures the first time. The unsupervised signatures that matched well with the supervised signatures were inspected, labeled with the appropriate class label, and removed from the classification process. The remaining confused clusters were grouped into general categories (e.g., forest, shrub, non-vegetation) and re-run through the process. Additionally, the "Summary" tool in Imagine was used to intersect the training site pixels with the unsupervised classes and examine the distribution of unsupervised pixels among the various land cover classes. This process mimics the statistical clustering algorithm previously described. These distributions were also used to aid in assigning class labels to the various unsupervised classes. Multiple iterations of these processes were repeated until all of the spectral classes were adequately matched and labeled, or until the remaining confused classes were spectrally inseparable.

Throughout the iterative classification process, interim checks of classification accuracy were performed by intersecting the classified image with the training sites to determine if the training sites were being accurately labeled by the classification. Areas with incorrectly classified training sites were run through further iterations of the supervised/unsupervised classification and further refined. The iterative process of interim accuracy assessments and refining classifications was terminated when the accuracy assessments indicated no improvements between one iteration and the next.

Editing and Modeling

Models that incorporated ancillary data sets such as elevation, slope, aspect, shaded relief, etc. helped to separate confused classes. For instance, terrain shadow/water confusion was easily corrected by creating a model using a shaded relief layer derived from DEMs. This worked relatively well for the majority of the image, but many areas had to be visually inspected and edited using on-screen digitizing because of the poor georectification of the DEM layer and TM image

For this project, the final steps of the classification process were to model the confused classes remaining after the iterative supervised/unsupervised classification process and to make final edits in areas that still had classification errors. Editing of classification errors was a process of comparing the classified image to the raw satellite image, aerial photography, and notes on field maps to identify errors remaining in the classification. These errors were then corrected by manually changing the class value for the pixels that were classified in error to their correct class value.

Accuracy Assessment

There are two primary motivations for accuracy assessment: (1) to understand the errors in the map (so they can be corrected), and (2) to provide an overall assessment of the reliability of the map (Gopal and Woodcock, 1992). Factors affecting accuracy included the number and location of test samples and the sampling scheme employed. Congalton (1991) suggested that 50 samples be selected for each map category as a rule of thumb. This value has been empirically derived over many projects. A second method of determining sample size includes using the multinomial distribution and specifying a given confidence in the estimate (Tortora 1978). The results of this calculation tend to favorably agree with Congalton's rule of thumb. Once a sample size is determined, it must be allocated among the categories in the map. A strictly proportional allocation is possible. However, the smaller categories in areal extent will have only a few samples that may severely hamper future analysis. The other extreme is to force a given number of samples from each category. Depending on the extent of each category, this approach can significantly bias the results. Finally, a sampling scheme must be selected. A purely random approach has excellent statistical properties, but is practically difficult and expensive to apply. A purely systematic approach is easy to apply, but could result in sampling from only limited areas of the map.

Alaska Perspective

Obtaining adequate reference data for performing an accuracy assessment can be extremely expensive in remote areas. Aircraft is the only means of transportation throughout most of Alaska. Aerial photographs are available for most of Alaska, but most are at a scale that makes it difficult if not impossible to distinguish some vegetation classes. Ideally, fieldwork would be performed during one summer, the classification would be performed during the winter, and the reference data would be collected the next summer. This procedure would allow a stratified random sample of the classification and ensure adequate sampling of all the classes. Unfortunately, this methodology is not typically feasible due to the cost of obtaining the field data in Alaska.

In this project, the fieldwork for obtaining the training sites for classifying the imagery and the reference data for the accuracy assessment was accomplished at the same time. Special care was taken during the preprocessing stage and in the field to make sure samples were obtained from all spectral classes within the image. However, funding limitations did not allow for the number of samples suggested for each class (n=50) for the accuracy assessment. Some earth cover classes were naturally limited in size and distribution, so that a statistically valid accuracy assessment sample could not be obtained without additional field time. For classes with low sample sizes few, if any, field sites were withheld for the accuracy assessment. This does not indicate that the classification for these types is inaccurate but rather that no statistically valid conclusions can be made about the accuracy of these classes. Withholding even a small percentage of sites for the accuracy assessment provided some confidence in the classification and guided the image processor and end user in identifying areas of confusion in the classification.

Selection of Accuracy Assessment Sites

Approximately one third of the collected field sites were set aside for use in the assessment of map accuracy while the remaining sites were utilized in the classification process. Unfortunately, given time and budget constraints it was not always possible to obtain enough sites per class to perform both the classification and a statistically valid accuracy assessment. A minimum of 15 sites in an individual class (5 for accuracy assessment, 10 for image processing training sites) were required before any attempt was made to assess the accuracy of that class. Classes with less than 15 field sites were still classified. However, much fewer, if any, field sites were utilized for accuracy assessment for these classes. Accuracy assessment sites were selected randomly across the project area to reduce bias.

While the accuracy assessment performed in this project is by no means a statistically robust test of the classification, it does give the user some understanding of the quality of the classification. It also provides enough detail for the end user to determine where discrepancies in the classification may cause a problem while using the data. It is important to note the variations in the dates of the imagery and field data. For this project, the imagery was from August 1999 and the field data was collected in July 2007. Differences due to environmental changes from the different sources may have had an impact on the accuracy assessment. A major assumption of quantitative accuracy assessments is that the label from the reference information represents the "true" label of the site and that all differences between the remotely sensed map classification and the reference data are due to classification and/or delineation error (Congalton and Green 1993). Unfortunately, error matrices can be inadequate indicators of map error because they are often confused by non-map error differences. Some of the non-map errors that can cause confusion are: registration differences between the reference data and the remotely sensed map classification, digitizing errors, data entry errors, changes in land cover between the date of the remotely sensed data and the date of the reference data, mistakes in interpretation of reference data, and variation in classification and delineation of the reference data due to inconsistencies in human interpretation of vegetation. In instances during the field work where the ground conditions had obviously changed from conditions at the date of image acquisition, field data was still collected to document the current conditions, but these sites were eliminated from the training and accuracy assessment procedures during the image classification process.

Error Matrix

The standard method for assessing the accuracy of a map was to build an error matrix, also known as a confusion matrix, or contingency table. The error matrix compares the reference data (field site or photo interpreted site) with the classification. The matrix was designed as a square array of numbers set out in rows and columns that expressed the number of sites assigned to a particular category in the reference data relative to the number of sites assigned to a particular category in the classification. The columns represented the reference data while the rows indicated the classification (Lillesand and Kiefer, 1994). An error matrix was an effective way to represent accuracy in that the individual accuracy of each category was plainly described along with both the errors of inclusion (commission errors) and errors of exclusion (omission errors) present in the classification. A commission error occurred when an area was included in a category it did not belong. An omission error was excluding that area from the category in which it did belong. Every error was an omission from the correct category and a commission to a wrong category. Note that the error matrix and accuracy assessment was based on the assumption that the reference data was 100% correct. This assumption was not always true. In addition to clearly showing errors of omission and commission, the error matrix was used to compute overall accuracy, producer's accuracy, and user's accuracy (Story and Congalton 1986). Overall accuracy was allocated as the sum of the major diagonal (i.e., the correctly classified samples) divided by the total number of samples in the error matrix. This value is the most commonly reported accuracy assessment statistic. Producer's and user's accuracies are ways of representing individual category accuracy instead of just the overall classification accuracy.

Results

Field Verification

Data were collected on 231 field sites during a six-day field season from 8/21/2007 through 8/26/2007. Only sixteen sites were visited during the two days of boat sampling due to the difficulty of hiking through the thick shrub swamps along the river, slower travel between sites in the jet boat, and greater time spent on each site familiarizing the crew with the vegetation species. Boat access was an inefficient method, but it was an important step in gaining an understanding of the vegetation species within various cover types which could not be obtained during the helicopter sampling since the helicopter was not allowed to land within the project area. An additional 215 sites were visited during three days of helicopter sampling. No sites were visited on August 24 because the helicopter was grounded due to poor visibility from weather. Approximately 30% (85) of the total field sites were set aside for accuracy assessment. Table 1 presents the distribution of sites by mapped class.

Table 1. Number of field sites visited per class

Map Class	Count
Treed Bog and Poor Fen	5
Poorly Drained Mixed Conifer Woodland - 10-25% cc	3
Poorly Drained Mixed Conifer Forest - 25-60% cc	9
Deciduous Forest - Cottonwood	17
Mixed Conifer and Deciduous Forest - Cottonwood / Sitka Spruce	1
Mixed Conifer Forest	31
Sitka Spruce Forest	16
Hemlock Forest	30
Shrub Swamp	9
Tall Shrub - Subalpine and Avalanche Slope	25
Tall Shrub Swamp - Riverine -	16
Dwarf Shrub Sphagnum Peatland	5
Freshwater Aquatic Bed	5
Freshwater Emergent Marsh	14
Fen and Wet Meadow	13
Intertidal Flat - Non-vegetated	1
Intertidal Flat - Vegetated	3
Lower Tidal and Brackish Marsh	4
Upper Tidal and Brackish Marsh	3
Coastal Meadow and Slough Levee - Carex and Forb dominated	8
Coastal Meadow and Slough Levee - Grass and Forb dominated	8
Sparsely Vegetated - Alpine and Rocky Outcrops	4
Sparsely Vegetated - Riverine	1
Total	**231**

Classification

Table 2 presents the acreage of map classes within the final land cover map for the Stikine project area. Forested classes accounted for 45% of the project area, with conifer forests representing 40% of the project area. Shrublands (25%) were the next most prominent cover type. Water, Bare / Sparsely Vegetated, and Other classes accounted for 25.5% of the project area, and Wetlands (4%) and Herbaceous (0.5%) areas represented the remainder of the project area. Figure 5 shows the final landcover map and displays the distribution of individual classes throughout the project area.

Modeling

Modeling was performed using a variety of ancillary data tools. The purpose of utilizing modeling in the classification and mapping process is to improve the evolving earth cover map by incorporating information other than spectral data to further discriminate between various vegetation types when spectral reflectance values alone have proven ineffective for doing such. A shaded relief image and an elevation zone image derived from USGS DEM at 1:250,000 scale were used in this regard. The shaded relief image was created in Erdas Imagine using the solar azimuth and solar elevation listed in the header file for the TM image. The DEM was often used to help separate spectrally confused classes like terrain shadow and deep water. Elevation images were also used to model cover types that were slope, aspect or elevation limited. While these slope, aspect, and/or elevation limitations did provide good consistent measures for correcting misclassifications throughout the study area, they were not always to be trusted to represent actual vegetation occurrence 100% of the time. Therefore, careful manual confirmation of model results were performed and anomalies corrected following the execution of each spatial model. This was especially true in areas where the georectification of the DEMs did not match the TM image.

Modeling was primarily used to identify misclassified areas. Since water, wetland classes, closed canopy forest and shadow have similar spectral signatures, these classes were often confused. Water obviously did not occur on a slope, but terrain shadows did, so a slope based model was used to search out shadowed areas that had been misclassified as water or wetlands. Shaded relief images were used to check for terrain shadow at higher elevations that had been misclassified as forest.

In addition to the use of DEM data to support modeling efforts, knowledge of ecological relationships and juxtaposition of vegetation types occurring throughout the study area were utilized to further refine the earth cover classification. For example, cottonwood was not found outside of the floodplains of the major rivers in the study area, so models were run to highlight pixels at high elevations and/or on steep slopes. These areas were then modeled and/or edited to a more appropriate map class (usually Tall Shrub – Subalpine/Avalanche). A second example includes a particular spectral signature for an aquatic bed type was found to possess a great amount of spectral confusion with open and closed canopy needleleaf types throughout the study

Table 2. Area of mapped classes within the project.

Class_name	Hectares	Acres	% Area		
Treed Bog and Poor Fen	389	961	0.26%		
Poorly Drained Mixed Conifer Woodland	1,914	4,730	1.26%		
Poorly Drained Mixed Conifer Forest	2,150	5,313	1.41%		
Deciduous Forest (Cottonwood)	4,730	11,688	3.10%		
Mixed Conifer and Deciduous Forest	485	1,198	0.32%		
Mixed Conifer Forest	22,361	55,257	14.67%		
Sitka Spruce Forest	18,556	45,854	12.17%		
Hemlock Forest	18,525	45,776	12.15%	Forest	45.09%
Tall Shrub Swamp - Fen Transition	2,216	5,477	1.45%		
Tall Shrub - Subalpine and Avalanche Slope	22,694	56,080	14.89%		
Tall Shrub Swamp - Riverine	10,048	24,834	6.59%		
Dwarf Shrub - Alpine	972	2,402	0.64%		
Dwarf Shrub Sphagnum Peatland	2,626	6,489	1.72%	Shrubs	25.30%
Freshwater Aquatic Bed	40	100	0.03%		
Freshwater Emergent Marsh	535	1,322	0.35%		
Fen and Wet Meadow1	1,425	3,521	0.93%	Freshwater	
Fen and Wet Meadow2	524	1,296	0.34%	Wetlands	1.91%
Mesic Herbaceous Meadow	696	1,720	0.46%	Herbaceous	0.46%
Intertidal Flat - Non-vegetated	3,501	8,653	2.30%		
Intertidal Flat - Vegetated	355	878	0.23%		
Lower Tidal Salt and Brackish Marsh	88	217	0.06%		
Upper Tidal Salt and Brackish Marsh	822	2,032	0.54%		
Coastal Meadow and Slough Levee 1	1,028	2,541	0.67%	Coastal	
Coastal Meadow and Slough Levee 2	741	1,832	0.49%	Wetlands	1.99%
Sparsely Vegetated - Riverine	679	1,678	0.43%		
Sparsely Vegetated - Other	2,938	7,261	1.94%		
Bare - Riverine	1,827	4,515	1.20%		
Bare - Other	1,896	4,685	1.24%	Bare/Sparse	7.11%
Clear Water	1,417	3,502	0.93%		
Turbid Water	16,638	41,114	10.92%		
Saltwater	3,600	8,897	2.36%	Water	14.21%
Ice/Snow/Glacier	2,404	5,942	1.58%		
Terrain Shadow	3,556	8,788	2.33%		
clouds	9	23	0.01%		
Other - flooded forest/shrub, dead trees	29	72	0.02%	Other	3.94%
Total	152,414	376,644	100.00%		100.00%

** Non-forest/Non-shrub freshwater wetlands only. Several classes within the Forested and Shrub groups are wetland types, also (e.g. – Tall shrub swamp classes, Poorly drained conifer classes, and most of the Deciduous and Mixed Conifer Deciduous classes could be considered forested wetlands).*

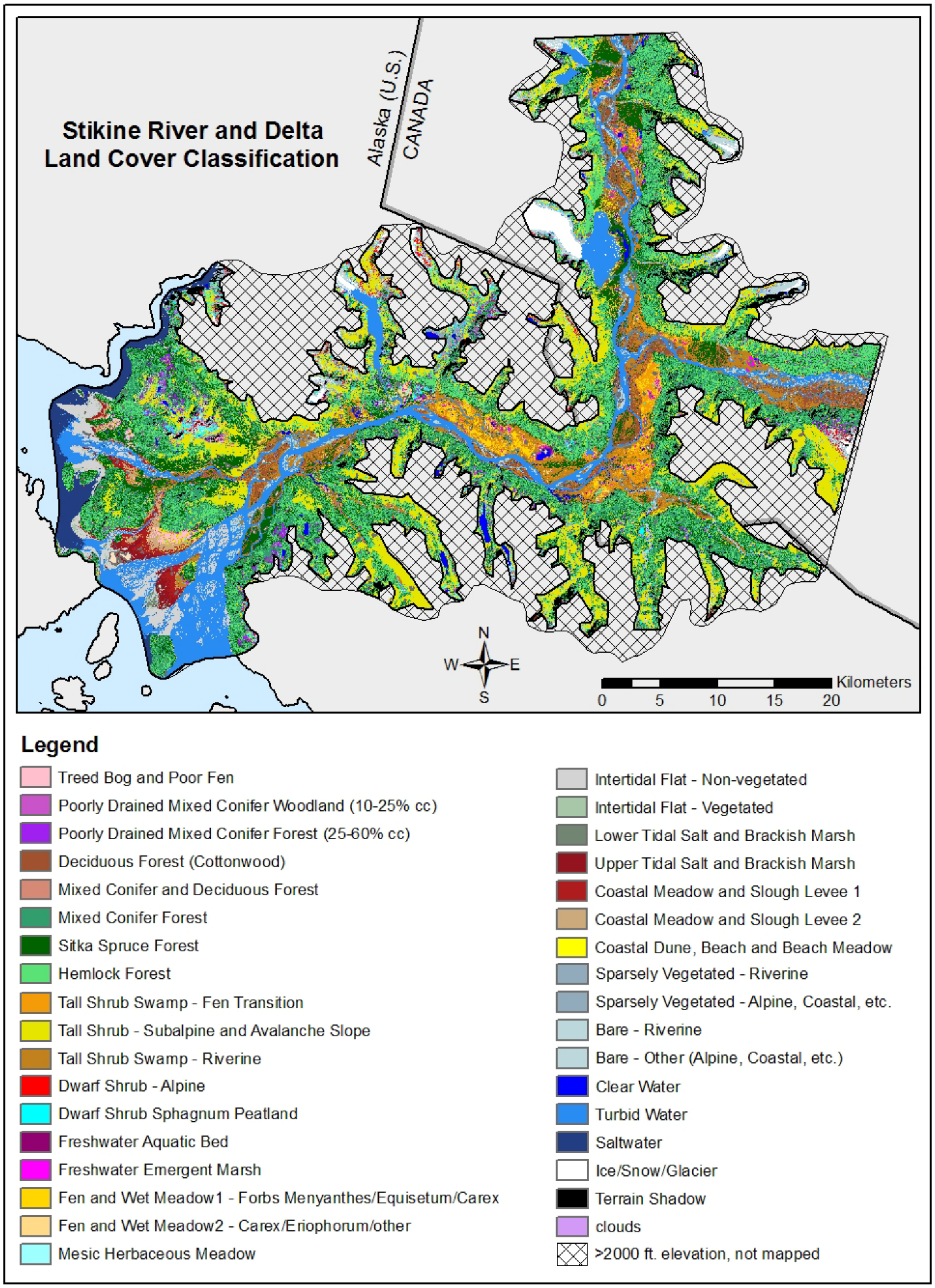


Figure 5. Stikine River and Delta Land Cover Mapping Project - Final classified map.

area. Simply labeling the signature to either aquatic bed or to a forested class produced errors either way. Therefore, a spatial model was developed that utilized "neighborhood analysis" to find those instances where this aquatic bed signature was surrounded by forested signatures and then re-labeled these specific occurrences of the signature to the appropriate forested class, while keeping the remaining pixels in the aquatic bed class. This type of model was used in many different forms to augment the spectral data in the development of the earth cover map. It is important to note that the modeling process was used primarily to identify *potentially* misclassified cover types throughout the study area. In order to maximize the reliability and classification accuracy in this mapping effort, manual review and editing techniques were utilized to correct the misclassified pixels to their appropriate mapping classification.

Editing

Editing was performed on all classes to various extents depending on how well the iterative classification process worked for each. The edits were verified with field sites, field photographs, aerial photography and field notes wherever possible. Some editing centered on ecological differences across the project area. For example, one signature classified large areas of the coastal meadow and slough levee class in the Stikine River delta area but also classified scattered pixels of fen and wet meadow in floodplain areas far away from the coast. Those pixels that occurred far from the coast were manually edited to the fen and wet meadow class.

Accuracy Assessment

The overall accuracy of the Stikine River and Delta land cover classification was above 80%. The accuracy assessment error matrices are presented in appendix (Tables B1, B2, B3). Three error matrices are presented. The first represents 83 sites reserved specifically for accuracy assessment. Note that 85 sites were originally set aside for accuracy assessment, but 2 sites fell within terrain shadow areas and were excluded from the error matrix. This matrix presents the most unbiased view of accuracy for the project because none of these sites were used to aid in the classification process. The overall accuracy statistic from these sites was 85% (Table B1). This is an unusually high level for a land cover map produced from Landsat TM imagery and containing this many map classes. The overall accuracy level based on these sites actually exceeded the 80% accuracy level of the training sites (Table B2). Typically, the accuracy level of training data will exceed that of the accuracy assessment sites. It is assumed that the very low sample size of accuracy assessment sites contributed to this surprisingly high accuracy level. It is also theorized that spatial autocorrelation may contribute to the unusually high accuracy levels because all field sites, both training sites and accuracy assessment sites, were gathered at the same time during one field season. The accuracy statistics in the matrix may be slightly elevated compared to an assessment conducted using reference sites gathered in a purely random fashion in a separate time frame from the training data. Because of these potential complications in the accuracy statistics, a third error matrix combining all field sites is also presented (Table B3). This table, although statistically biased because it includes training data, presents the largest sample size. For practical purposes when utilizing this data, it would be safest to assume that the overall accuracy of the map product is at best 80% (the lowest of the three values). It should be noted that no reference sites for the water classes are included in the error matrices. These classes are consistently mapped at greater than 80% accuracy in almost any Landsat TM derived map, and would only serve to elevate the overall accuracy statistics.

Final Products

The final products included a digital earth cover classification and a digital database of field data collected at 231 sites visited within the project area. The digital earth cover classification was delivered in ArcGIS file geodatabase format and in Erdas Imagine format. The field site database tables were stored as digital tables in Microsoft Access. Digital photos of the field sites were stored in jpeg format.

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Appendix A. Class List and Descriptions for Stikine Landcover Classification

Landcover Class List

Class #	Class Name
1	<u>Forest</u>
	10% - 25% crown cover (*generally Peatlands*)
2	Treed Bog and Poor Fen (Shore Pine or Mountain Hemlock/Mixed Conifer)
	10% - 60% crown cover (*generally low productivity forests*)
3	Poorly Drained Mixed Conifer Woodland (10% - 24% cc)
4	Poorly Drained Mixed Conifer Forest (25% - 60% cc)
	25% - 60% crown cover (*generally mid- to high-productivity forests*)
5	Deciduous Forest (Cottonwood)
6	Mixed Conifer and Deciduous Forest (Sitka Spruce / Cottonwood)
7	Mixed Conifer Forest
8	Sitka Spruce Forest
9	Hemlock Forest
10	<u>Shrubs</u>
11	Tall Shrub Swamp – Fen Transition (Open Tall Shrub Alder with sedge/sphagnum/wet forbs)
12	Tall Shrub – Other (Subalpine or Avalanche Slope)
13	Tall Shrub Swamp – Riverine
14	*
15	Dwarf Shrub – Alpine
16	Dwarf Shrub Sphagnum Peatland
20	<u>Herbaceous</u>
21	Freshwater Aquatic Bed
22	Freshwater Emergent Marsh
23	Fen and Wet Meadow 1 (Forb dominated – menyanthes/equisetum/carex)
24	Fen and Wet Meadow 2 (Sedge dominated – Carex/Eriophorum/other)
25	Mesic Herbaceous Meadow
30	<u>Coastal Systems</u>
31	Intertidal Flat – Non-vegetated
32	Intertidal Flat – Sparsely vegetated
33	Lower Tidal Salt and Brackish Marsh
34	Upper Tidal Salt and Brackish Marsh
35	Coastal Meadow and Slough Levee 1 – sedge and forb dominated
36	Coastal Meadow and Slough Levee 2 – grass and forb dominated
37	Coastal Dune, Beach and Beach Meadow
40	<u>Sparsely Vegetated and Bare</u>
41	Sparsely Vegetated – Riverine
42	Sparsely Vegetated – Alpine, coastal and other rocky outcrops
43	Bare – Riverine
44	Bare - Alpine, coastal and other rocky outcrops
50	<u>Water</u>
51	Clear Water
52	Turbid Water
53	Saltwater
60	<u>Other</u>
61	Terrain or Cloud Shadow
62	Cloud
63	Other – Flooded forest or dead trees

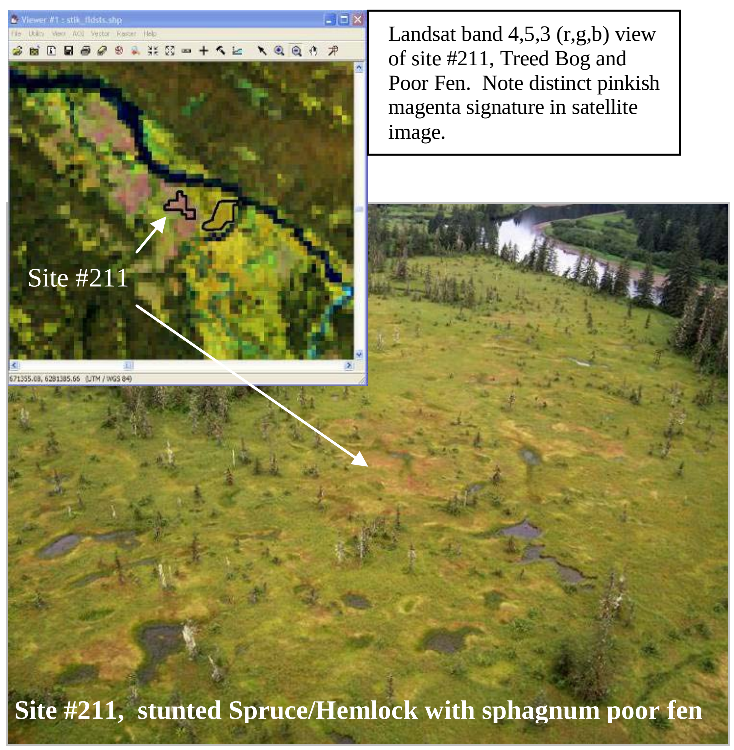
** Intentionally blank. Originally reserved for a low shrub class, but no low shrub classes were observed during field season, nor mapped in final map*)
*** Not observed during field sampling and not mapped in the final land cover map.*

Landcover Class Descriptions
TREED/FORESTED CLASSES
Class 2. Treed Bog and Poor Fen

(*from NatureServe 2008*) “This ecological system is a mosaic of shore pine-, dwarf-shrub- and herbaceous-dominated peatland communities. It includes well-developed peatlands on flat, rolling, or sloping terrain. Soils are poorly drained with deep organic layers. Trees are usually stunted and the tree canopy typically has less than <30% cover. Common species include *Pinus contorta, Chamaecyparis nootkatensis (= Cupressus nootkatensis), Empetrum nigrum, Kalmia, Ledum* spp., *Vaccinium uliginosum, Carex aquatilis var. dives (= Carex sitchensis), Carex pluriflora, Carex pauciflora, Carex livida, Trichophorum caespitosum, Eriophorum angustifolium, Sanguisorba menziesii*, and *Cornus canadensis*. *Sphagnum* spp. dominate the moss layer. This system includes a range of canopy structures and compositions from mixed conifer peatlands on sideslopes and benches with *Chamaecyparis nootkatensis, Tsuga mertensiana, Tsuga heterophylla*, and *Pinus contorta*, to peatlands on level ground with scrub *Pinus contorta*.”

Project specific comments:

This class was typically observed at low elevations (<150 m, <500 ft) on flat to slightly sloping terrain. Spectrally it was defined by areas that were dominated by sphagnum mosses that exhibited a distinct magenta signature in a band 4,5,3 (r,g,b) false-color combination. The signature represented treed bogs (both shore pine and mixed conifer bogs) as well as sparse ericaceous shrub bogs with little or no tree cover. In the landcover map this class is most often confused with and overlaps with the Dwarf Shrub Sphagnum Peatland class (*class #16*) and the Poorly Drained Conifer Woodland class (*class #3*). *Note: In the coastal meadows of Farm Island, there are several areas that, spectrally, fell into this class. While it is certain that these areas are sphagnum dominated bogs and poor fens, it is likely that many of them are treeless and might belong in the dwarf shrub sphagnum peatland class. However, these areas fell within a project imposed no-fly zone of locations within a - mile buffer of cabin sites so this assumption could not be verified.*



Example Site Photos for Treed Bog and Poor Fen class

Classes 3 and 4. Poorly Drained Mixed Conifer Woodland
(*from NatureServe 2008*) "This ecological system occurs on low to mid elevations on rolling terrain, benches, and gentle slopes with restricted drainage from Kenai Fjords through southeast Alaska. Soils may be shallow to deep, are poorly drained, and usually have a thick organic layer or some peat development. In some places, stands are often a fine mosaic of peatlands and better-drained inclusions. These are low-productivity sites that are intermediate between shore pine or mountain hemlock peatland sites and productive forest systems. The forest canopy is open (less than 45% cover), and trees often show signs of stress such as spike-top (especially cedar) or chlorotic foliage (especially spruce). Standing dead trees are common. In the north, paludification on these sites may lead to conversion from mountain hemlock to mountain hemlock peatland over long time scales. Overstory trees may include several of the following species: *Tsuga heterophylla, Tsuga mertensiana* (often alone or with *Picea sitchensis* in the subpolar rainforest zone), *Thuja plicata* (southern portion of the Alaska distribution only), and *Chamaecyparis nootkatensis (= Cupressus nootkatensis)*. *Picea sitchensis* and *Pinus contorta* may also be present but are not dominant. Common shrubs include *Vaccinium ovalifolium, Gaultheria shallon* (southern portion of the Alaska distribution only), and *Elliottia pyroliflorus*. Common understory species include *Nephrophyllidium crista-galli, Thelypteris quelpaertensis, Phegopteris connectilis, Trichophorum caespitosum, Carex anthoxanthea, Carex pluriflora, Carex stylosa, Eriophorum* spp., *Lysichiton americanus*, and *Sphagnum* spp."

Project specific comments:
The Poorly Drained Mixed Conifer Woodland class from the Ecological Systems of Alaska (NatureServe 2008) was split into two crown cover classes for the Stikine project area. Class #3, the woodland class, represents the transition into the Dwarf Shrub Sphagnum Peatland and Treed Bog and Poor Fen class and therefore includes the lowest productivity areas in the forested classes. Class #4, Poorly Drained Conifer Forest, represents the remainder of the low productivity forested areas in the project area.

Class 3 - Poorly Drained Mixed Conifer Woodland. This class, having 10-25% crown closure, represents woodland areas that overlap or form the transition into the Treed Bog and Poor Fen class (Class #2), but sites in this class were not as dominated by sphagnum moss and therefore did not exhibit the distinct pinkish-magenta spectral signature of the Treed Bog and Poor Fen class.

This class also includes the Mesic Subalpine Parkland class as defined by NatureServe (2008). The project area was limited to elevations below 2000 feet as a requirement of the helicopter safety plan, so only a few sites were observed in the Parkland class. Although the Parkland class is generally more mesic, it was grouped with the spectrally similar Poorly Drained Conifer Woodland class since the sample size was insufficient to map it as a separate class. The Poorly Drained Conifer Woodland class was found at all elevations throughout the project area. In the landcover map this class is most often confused with and overlaps with the Dwarf Shrub Sphagnum Peatland class (*class #16*) and the Poorly Drained Conifer Forest class (*class #4).*

Class 4 - Poorly Drained Mixed Conifer Forest. Field sites for this class were typically mixed conifer sites with crown closures between 25% and 60%, but typically 45% or less. For all field sites that were visited, western hemlock remained the dominant or a co-dominant species mixed with Alaska yellow-cedar, mountain hemlock, or subalpine fir.

The class was found at all elevations throughout the project area. In the landcover map this class is most often confused with the Poorly Drained Conifer Woodland class (class #3) and to a lesser extent with the Mixed Conifer class (class #7) and the Sitka Spruce class (class #8).

Example site photos for Poorly Drained Conifer Woodland class (class #3).

Example site photos for Poorly Drained Conifer Forest class (class #4).

Class 5. Deciduous Forest

This class represents areas with ≥ 25% tree cover where deciduous trees comprise ≥ 75% of the tree cover. Within the Stikine project area this class represents *Populus balsamifera* (cottonwood) forests only. It was observed and mapped only in the floodplain areas of the major rivers within the project area. Only one other deciduous forest type was observed within the project area during the field work. This second deciduous type was uncommon and consisted of *Alnus rubra* (red alder) or more often a mixture of *Alnus rubra*, a tree-sized *Salix* spp., and *Populus balsamifera*. This *Alnus rubra* or mixed deciduous type was spectrally confused with the Riverine Tall Shrub class (class #11) and was spatially intermixed with the Tall Shrub class so it was mapped as part of the Tall Shrub class. In the Ecological Systems of Alaska classification scheme (NatureServe 2008) all three of these deciduous types (cottonwood; red alder / mixed deciduous; and riverine tall shrub) are included within the single Alaska Pacific Maritime Floodplain Forest and Shrubland class.

Example Site Photos for the Deciduous Class (class #5).

Class 6. Mixed Conifer and Deciduous Forest

This class represents areas with ≥ 25% tree cover where conifer species account for < 75% of the tree cover and deciduous species account for <75% of the tree cover. These mixed conifer and deciduous stands were uncommon throughout the project area. Species composition is almost always a mixture of *Populus balsamifera* and *Picea sitchensis*. A *Picea sitchensis* and *Alnus rubra* type was observed in very limited locations, but always at a spatial extent that was too small to sample or map. This class is found on islands within the major rivers, on alluvial outwash plains, and on glacial moraines. In the landcover map this class is most often confused with the closed deciduous class (class #5) and with open Sitka spruce stands having a closed tall shrub understory.

Example Site Photo for the Mixed Conifer and Deciduous Class (class #6).

Class 7. Mixed Conifer Forest

This class represents areas with ≥ 25% tree canopy cover where conifer species comprise ≥ 75% of the tree cover but no single conifer species comprises ≥ 75% of the conifer tree cover. This class represents all mid- to high-productivity mixed conifer forest types. Within the Stikine project area, the most common co-dominance type was a mixture of *Tsuga heterophylla* and *Picea sitchensis*. *Tsuga mertensiana* and *Picea sitchensis* mixtures were also observed at higher elevations. *Chamaecyparis nootkatensis* and *Abies lasiocarpa* were also observed in some field sites within this class, but always as subordinate species.

Example photos of the Mixed Conifer class (class #7)

Class 8. Sitka Spruce Forest

This class represents areas with $\geq$ 25% tree canopy cover where conifer species comprise $\geq$ 75% of the tree cover and *Picea sitchensis* comprises $\geq$ 75% of the conifer tree cover. The class is found at all elevations in the project area. On slopes and steeper terrain outside of the major river floodplains *Tsuga heterophylla*, *Tsuga mertensiana*, and *Chamaecyparis nootkatensis* are typically present, but the combined canopy cover of these other species does not reach 25%. This class is often associated with disturbance areas (e.g., very steep slopes, alluvial fans, and ancient landslides) (NatureServe, 2008). In the major river floodplains the Sitka Spruce class is typically pure stands of *Picea sitchensis* or mixtures of *Picea sitchensis* with some *Populus balsamifera*. On slopes, the Sitka Spruce class typically has a minor percentage of *Tsuga heterophylla* or *Tsuga mertensiana* included. In the landcover map this class is most often confused with Hemlock Forest (class #9) and Mixed Conifer Forest (class #9). Spectrally, it is also confused with the "dark" emergent marsh (class #22) and Clear Water (class #51) classes.

Example photos of the Sitka Spruce class (class #8)

Class 9. Hemlock Forest

This class represents areas with $\geq$ 25% tree canopy cover where conifer species comprise $\geq$ 75% of the tree cover and *Tsuga heterophylla* and/or *Tsuga mertensiana* comprise $\geq$ 75% of the conifer tree cover. The class is found at all elevations in the project area. With the limited number of field sites for the project, western hemlock and mountain hemlock could not be separated spectrally, and even with larger sample sizes these two hemlock types are probably not spectrally separable. Western hemlock forest was found at all elevations within the project area, while mountain hemlock forest was limited to the higher elevations. Species associations for these two hemlock forest types can be found in the Ecological Systems of Alaska (NatureServe 2008). In the landcover map, this class is most commonly confused with Sitka Spruce Forest (class #8) and Mixed Conifer Forest (class #9).

Example photos of the Hemlock class (class #9)

SHRUB CLASSES

Tall Shrubs

Three separate tall shrub classes were mapped within the project area. Although there was significant spectral confusion between all of these classes, use of contextual information about site location derived from DEMs, digital aerial photography, and "photo-interpretation" of the Landsat imagery allowed these relatively distinct ecological sub-classes to be mapped with relative reliability. The following are descriptions of the three mapped tall shrub classes:

Class 11. Tall Shrub Swamp – Fen Transition

(*from NatureServe 2008, North Pacific Shrub Swamp class*) "Swamps vegetated by shrublands occur throughout the Pacific Northwest Coast, from Cook Inlet and Prince William Sound, Alaska, to the southern coast of Oregon. These are deciduous broadleaf tall shrublands that are located in depressions, around lakes or ponds, or river terraces where water tables fluctuate seasonally (mostly seasonally flooded regime), in areas that receive nutrient-rich waters. These depressions are poorly drained with fine-textured organic, muck or mineral soils and standing water common throughout the growing season. *Alnus viridis ssp. sinuata* often dominates the shrub layer, but many *Salix* species may also occur. The shrub layer can have many dead stems. However, various species of *Salix*, *Spiraea douglasii*, *Malus fusca*, *Cornus sericea*, *Alnus incana ssp. tenuifolia (= Alnus tenuifolia), Alnus viridis ssp. crispa (= Alnus crispa)*, and/or *Alnus viridis ssp. sinuata (= Alnus sinuata)* can be the major dominants. They may occur in mosaics with marshes or forested swamps, being on average more wet than forested swamps and more dry than marshes. However, it is also frequent for them to dominate entire wetland systems... **Wetland species, including *Carex aquatilis var. dives (= Carex sitchensis), Carex utriculata, Equisetum fluviatile*, and *Lysichiton americanus*, dominate the understory. On some sites, *Sphagnum* spp. are common in the understory (Stikine, Yakutat Forelands, Copper River Delta).**"

Project specific comments:

This class represents an area of transition between the Fen and Wet Meadow classes (class #23 and class #24) and the Tall Shrub Swamp – Riverine class (Figure A-1). In the Stikine landcover map it always indicates very open canopy tall shrub alder (*Alnus viridis).* Often the understory included significant amounts of *Sphagnum* spp., *Eriophorum* spp. and other forbs described in the two Fen and Wet Meadow classes (Classes 23 and 24), but the presence of > 25% tall shrub, often accompanied by the presence of swamp indicators such as *Lysichiton americanus*, fitted these areas into the Tall Shrub Swamp class. This class was observed and mapped only in the flat floodplain areas along the major rivers within the project area.

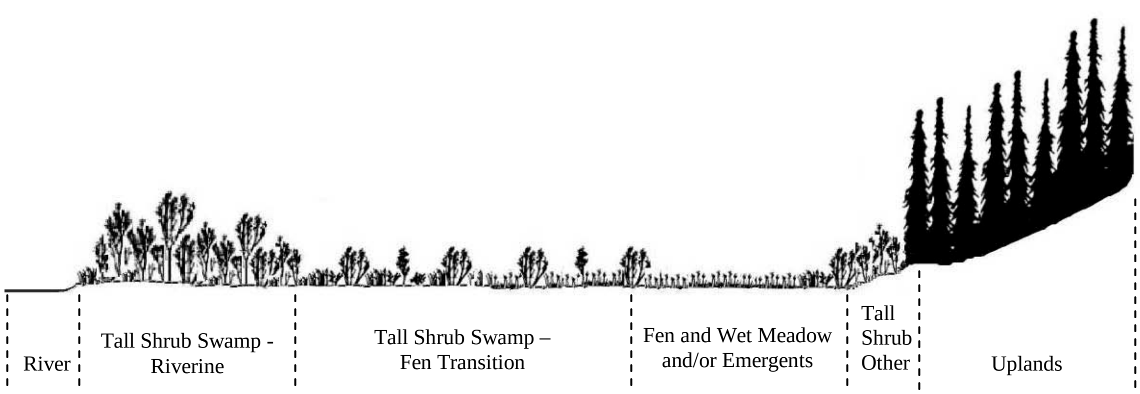
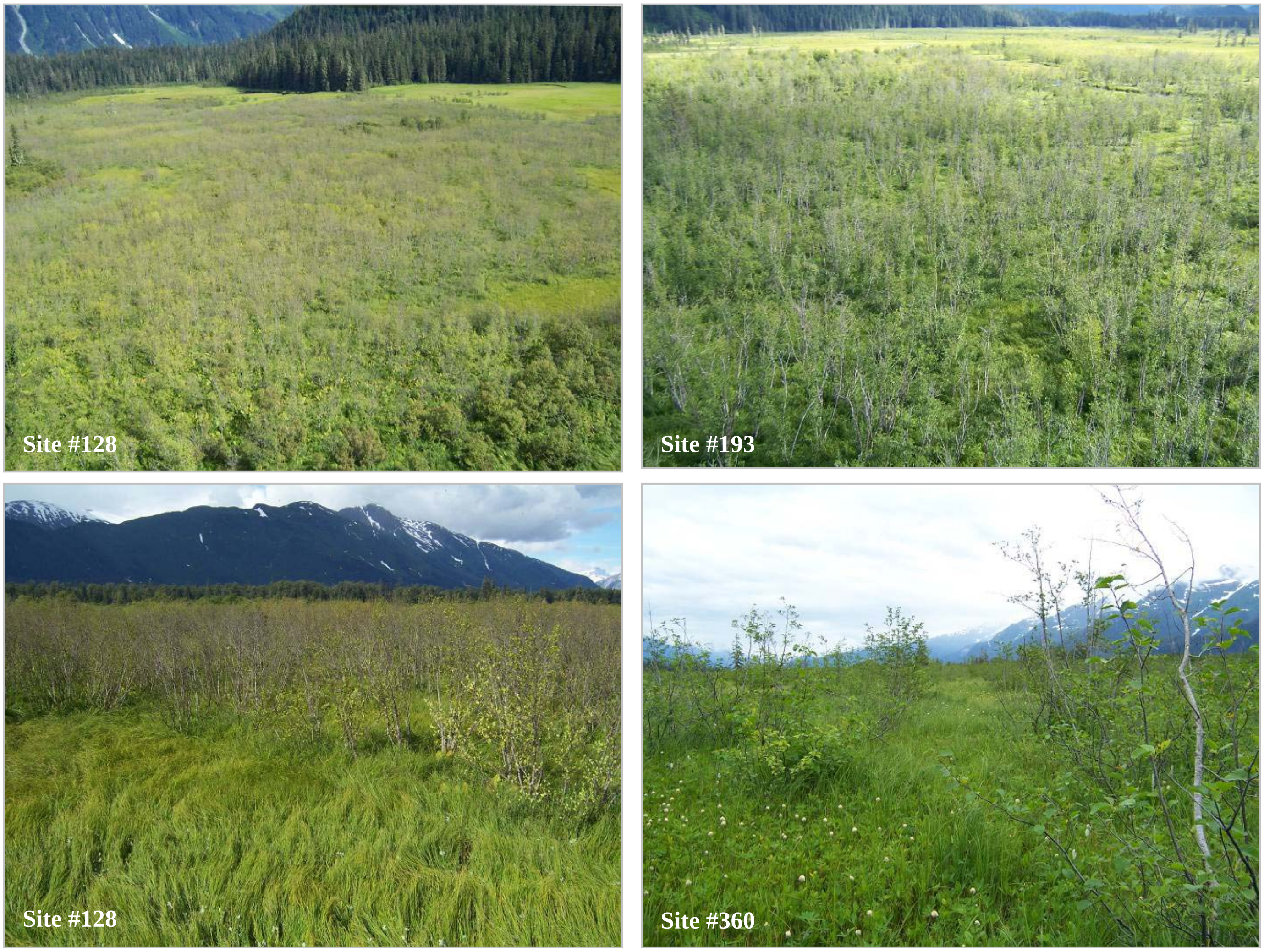


Figure A-1. Example cross-section of common floodplain class distribution.



Example photos of Tall Shrub Swamp – Fen Transition class (class #11)

Class 12. Tall Shrub – Other / Subalpine / Avalanche Slope

(*from NatureServe 2008, Alaskan Pacific Maritime Subalpine Alder-Salmonberry Shrubland*)
"*Alnus viridis ssp. sinuata* is often the dominant species, but *Rubus spectabilis* may be codominant. Other common species include *Sambucus racemosa, Oplopanax horridus*, and *Elliottia pyroliflorus*. The tall shrub system is often mosaiced with the mesic herbaceous meadow system. Common herbaceous species include *Calamagrostis canadensis, Chamerion angustifolium, Veratrum viride, Heracleum maximum, Athyrium filix-femina, Dryopteris expansa, Phegopteris connectilis, Equisetum arvense, Streptopus amplexifolius, Lupinus nootkatensis, Valeriana sitchensis, Geranium erianthum, Aconitum delphiniifolium, Castilleja unalaschcensis, Sanguisorba canadensis*, and *Carex macrochaeta*"

Project specific comments:
This class represents areas with less than 25% tree cover, greater than 25% shrub cover, where tall shrubs (> 1.3 m) dominate the site, and the site is above the floodplain of the major rivers within the project area. This class includes both the Alaskan Pacific Maritime Avalanche Slope Shrubland and the Alaskan Pacific Maritime Subalpine Alder-Salmonberry Shrubland of the Ecological Systems of Alaska classification (NatureServe 2008). It was impossible to spectrally

separate these two systems from the NatureServe classification, and their species assemblages are nearly identical so they were grouped into the single Tall Shrub - Other class for the Stikine mapping project.

Spectrally, when found on southerly facing slopes, this class could be separated from the Tall Shrub Swamp – Riverine class (class #13). However, on northerly aspects there was significant spectral confusion with the Tall Shrub Swamp – Riverine class. For the final Stikine land cover map, all shrub pixels that fell outside of the floodplains of the major rivers in the project area were edited to the Tall Shrub - Other class and shrub pixels within the floodplains of the major rivers were edited to the Tall Shrub – Riverine class. The boundary between the floodplain and upland areas was determined through on-screen photo interpretation of digital aerial photography, on-screen visual interpretation of the satellite imagery, and reference to the available DEM layer. A simple model of the floodplain based on slope, aspect, and elevation derived from the DEM layer could not be utilized because the DEM layer and Landsat image were not accurately georeferenced.

Example photos of Tall Shrub – Other class (class #12)

Class 13. Tall Shrub Swamp – Riverine

(*from NatureServe 2008, North Pacific Shrub Swamp class*) "Swamps vegetated by shrublands occur throughout the Pacific Northwest Coast, from Cook Inlet and Prince William Sound, Alaska, to the southern coast of Oregon. These are deciduous broadleaf tall shrublands that are located in depressions, around lakes or ponds, or river terraces where water tables fluctuate seasonally (mostly seasonally flooded regime), in areas that receive nutrient-rich waters. These depressions are poorly drained with fine-textured organic, muck or mineral soils and standing water common throughout the growing season. *Alnus viridis ssp. sinuata* often dominates the shrub layer, but many *Salix* species may also occur. The shrub layer can have many dead stems. However, various species of *Salix*, *Spiraea douglasii*, *Malus fusca*, *Cornus sericea*, *Alnus incana ssp. tenuifolia (= Alnus tenuifolia)*, *Alnus viridis ssp. crispa (= Alnus crispa)*, and/or *Alnus viridis ssp. sinuata (= Alnus sinuata)* can be the major dominants. They may occur in mosaics with marshes or forested swamps, being on average more wet than forested swamps and more dry than marshes. However, it is also frequent for them to dominate entire wetland systems... Wetland species, including *Carex aquatilis var. dives (= Carex sitchensis)*, *Carex utriculata*, *Equisetum fluviatile*, and *Lysichiton americanus*, dominate the understory. On some sites, *Sphagnum* spp. are common in the understory (Stikine, Yakutat Forelands, Copper River Delta)."

Project specific comments:
This class represents areas with less than 25% tree cover, greater than 25% shrub cover, where tall shrubs (> 1.3 m) dominate the site, and the site is within the floodplain of the major rivers within the project area. *Alnus spp.* (presumed *Alnus viridis)* was present in all field sites visited, but *Salix* spp., *Sambucus racemosa*, *Cornus stolonifera*, *Rubus spectabilis*, and *Populus balsamifera* were all common components. This class typically represents slightly drier areas than Tall Shrub Swamp – Fen Transition class (class #11). It is widespread and situated along the islands, banks and terraces associated with the main channels and sloughs of the large rivers in the project area (Figure A-1). While the water table is always at or above the surface in the Tall Shrub Swamp – Fen Transition class, the water table tends to be at or slightly below the surface in the Tall Shrub Swamp – Riverine class.

This class was observed and mapped only in the flat floodplain areas along the major rivers within the project area. It was spectrally confused with the Tall Shrub - Other class on north facing aspects. For the final Stikine land cover map, all shrub pixels that fell outside of the floodplains of the major rivers in the project area were edited to the Tall Shrub - Other class and shrub pixels within the floodplains of the major rivers were edited to the Tall Shrub Swamp – Riverine class. The boundary between the floodplain and upland areas was determined through on-screen photo interpretation of digital aerial photography, on-screen visual interpretation of the satellite imagery, and reference to the available DEM layer. A simple model of the floodplain based on slope, aspect, and elevation derived from the DEM layer could not be utilized to define this boundary because the DEM layer and Landsat image were not accurately georeferenced.

One exception was made to the percent cover rules for this class. A few field sites were visited where Alnus rubra and a tree-sized (8 meters) Salix species combined to form greater than 25% tree cover. Although these sites technically fit into a mixed deciduous tree class, they were very uncommon, always included a large component of other tall shrub species, were always associated with or surrounded by tall shrub swamp, and were spectrally confused with the tall shrub swamp signature. For these reasons they were grouped and mapped with the Tall Shrub Swamp – Riverine class.

Example photos of Tall Shrub Swamp – Riverine class (class #13)

Class 14. Intentionally Blank

Class #14 was initially reserved for a "Low Shrub" class (e.g. – Alaskan Pacific Maritime Wet Low Shrubland or Alaskan Pacific Maritime Subalpine Copperbush Shrubland). However, no low shrub types were observed within the project area so class #14 remained unused in the map.

Class 15. Dwarf Shrub – Alpine

(*from NatureServe 2008, Alaskan Pacific Maritime Alpine Dwarf-Shrubland class*) "This system occurs primarily on alpine and subalpine sites of southeastern, maritime Alaska, but it can also be found at lower elevations (e.g., Kenai Fjords and Prince William Sound). It occurs on sideslopes, shoulder slopes, and low summits, and the terrain varies from gently sloping to steep. The vegetation can be a mosaic of herbaceous meadow and alpine heath (dwarf-shrublands) or herbaceous meadow with a heath understory; however, in some areas dwarf-shrub cover is continuous. Dominant dwarf-shrub species include *Empetrum nigrum, Phyllodoce aleutica, Phyllodoce glanduliflora, Cassiope mertensiana, Cassiope tetragona, Harrimanella stelleriana*, and *Luetkea pectinata*. Other common species may include *Vaccinium uliginosum, Vaccinium vitis-idaea*, and *Loiseleuria procumbens*. Ericaceous species typically dominate this type, but sites dominated by *Salix arctica* and *Salix reticulata* are included in this system. Scattered tall shrubs and dwarf trees may be present. Common herbaceous species include *Carex macrochaeta, Lupinus nootkatensis, Valeriana sitchensis, Geranium erianthum, Aconitum delphiniifolium, Castilleja unalaschcensis, Sanguisorba canadensis, Anemone narcissiflora, Artemisia arctica*, and *Viola* spp. On slopes on the outer coast and also in Kenai Fjords and Prince William Sound *Nephrophyllidium crista-galli* is common in this system."

Project specific comments:

No field sites were visited in this class because of the Helicopter Safety Plan and restrictions in flying at high elevations. However, a few areas of this class that fell below the 2000' elevation line marking the project area boundary were observed at a distance during the field work and notes were taken on the field maps. When the mapping was performed, signatures that intersected with these sites were mapped into this class. From a distance, the dominant species in these sites appeared to be alpine heathers (*Phyllodoce* spp., *Cassiope* spp. or *Empetrum nigrum*). This class was typically interspersed at high altitudes with subalpine fir or mountain hemlock parklands that were mapped into the Poorly Drained Conifer Forest class (class #4). There appeared to be some spectral confusion between this class and the Dwarf Shrub Sphagnum Peatland class, as well as with the Mesic Herbaceous Meadow class at high altitudes.

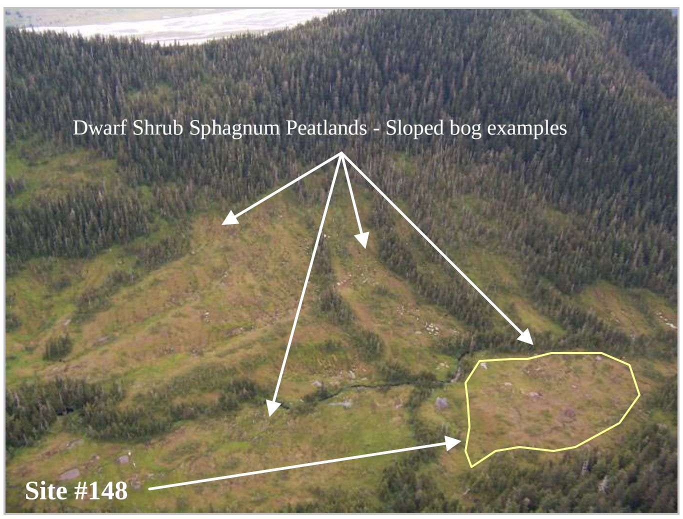
Example photo of Dwarf Shrub – Alpine class (Class #16)

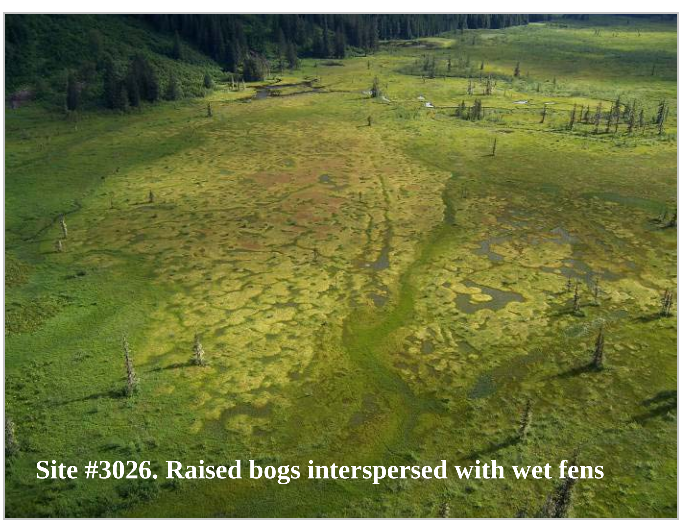
Class 16. Dwarf Shrub Sphagnum Peatland

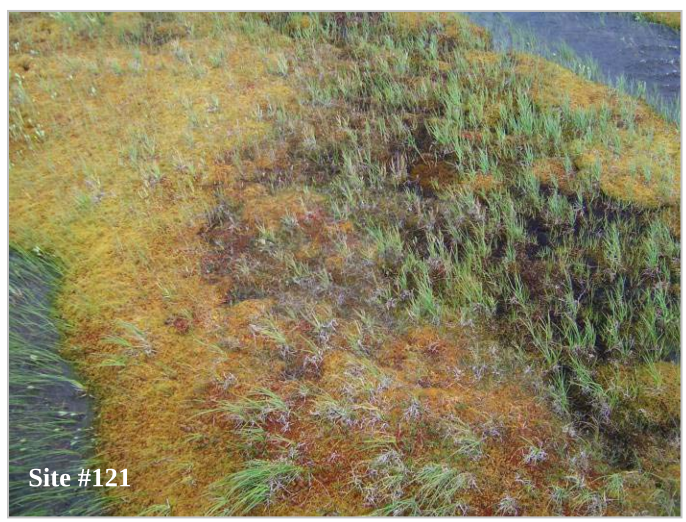
(<u>*from NatureServe 2008, Alaskan Pacific Maritime Dwarf-Shrub-Sphagnum Peatland class*</u>) "This ecological system is a mosaic of dwarf-shrub- and herbaceous-dominated peatlands. It includes well-developed peatlands (bogs and poor fens) in basins or on flat to gently sloping terrain. Soils are acidic and are usually saturated throughout the growing season. *Sphagnum* spp. (especially *Sphagnum fuscum*) dominate the ground layer. Shrub cover is typically low and may include *Ledum* spp., *Andromeda polifolia, Kalmia polifolia*, *Vaccinium oxycoccos (= Oxycoccus microcarpos)*, *Empetrum nigrum*, and *Vaccinium uliginosum*. Other common species include *Drosera* spp., *Carex livida*, *Carex pluriflora*, *Carex pauciflora*, *Carex aquatilis var. dives (= Carex sitchensis), Trichophorum caespitosum*, and *Eriophorum angustifolium*. This system includes raised bogs."

Project specific comments:

This class was observed at all elevations throughout the project area, from flat bog areas in the floodplains of the major river, to poorly drained "sloped-bogs" on hillsides, rounded knobs and hilltops. This class is very similar to both the Treed Bog and Poor Fen class (class #2) and the Poorly Drained Conifer Woodland class (class #3), and often represents the understory of both of those treed classes. Within the floodplains of the major rivers, this class often formed a "strangmoor"-like mosaic of raised bogs interspersed with wet poor fens and pools of open water. These sites typically interspersed with and transitioned into the Fen and Wet Meadow class (class #23).







Class 21. Freshwater Aquatic Bed.

This class includes small lakes, ponds, and ox-bows with at least 20% of the water surface covered by floating and/or slightly submerged aquatic vegetation. Common floating species included *Nuphar* spp. and *Potamogeton* spp. This class was observed and mapped only in basins and oxbows within the floodplain of the Stikine River. Large (> 1-2 hectares) aquatic beds were relatively uncommon and mostly restricted to larger, well established ponds or lakes in the floodplain. Very narrow patches and bands of aquatic bed were relatively common between open water and freshwater emergent marsh, but these bands of vegetation were typically too narrow to map using the available 30 meter Landsat imagery.

Example photos of Aquatic Bed class (Class #21).

Class 22. Freshwater Emergent Marsh

This class represents areas of permanent or semi-permanent standing water with at least 20% cover of wet forb species emerging through the water surface. *Menyanthes trifoliata*, *Equisetum fluviatile*, *Carex aquatilis var. dives (= Carex sitchensis)*, and *Comarum palustre* were typically the dominant/co-dominant species. This class transitions into the Fen and Wet Meadow classes (classes 23 and 24), which include the same wet forb species emerging from wet sphagnum. The class was common throughout the floodplains of the major rivers in the study area. Although this class was only observed in the major floodplains of the project area, it is likely found at all elevations throughout the project area in small bands surrounding ponds, lakes, and other small waterbodies.

Classes 23 and 24. Fen and Wet Meadow

(*from NatureServe 2008, Alaskan Pacific Maritime Fen and Wet Meadow*) "This ecological system includes herbaceous wetlands in fens (not including bogs) and non-peatlands. The fen/wet meadow system may be dominated either by sedges, sedges with a variety of forbs, or forbs. The organic layer ranges from thick to thin, and may be composed of sphagnum, sedge, or other organic material and can occur over mineral soil, or may be floating or submerged. Rich fens consistently feature *Carex aquatilis var. dives (= Carex sitchensis)*, although a variety of other sedges and forbs may be present, including *Dodecatheon pulchellum, Parnassia fimbriata, Eriophorum russeolum, Menyanthes trifoliata*, and *Comarum palustre*. Ericaceous shrubs are absent. Bryophytes (when present) include *Calliergon giganteum, Sphagnum squarrosum*, and *Sphagnum riparium*. Mixed sedge and forb meadows include *Carex saxatilis, Carex lyngbyei, Sanguisorba canadensis, Swertia perennis*, and *Platanthera dilatata*. Forb-dominated sites include *Equisetum fluviatile, Comarum palustre (= Potentilla palustris)*, and *Menyanthes trifoliata*."

Project specific comments:

This class was common throughout the floodplains of the major rivers in the project area and was limited to these low elevations. This single class from the Alaska Ecological Systems classification was split into two separate classes based on spectral characteristics in the image that appear to match some vegetation patterns in the field sites. Class #23 represents sites that are more dominated by sphagnum and forbs, especially *Menyanthes trifoliate, Equisetum fluviatile, and Comarum palustre*. Class #24 tends to represent sites that have a higher percentage of sedges (e.g. – Carex aquatilis var. dives and eriophorum species) and often less sphagnum than class #23. Class #24 may represent more of the wet meadow side of this class. These observations are based on a very limited number of field sites, and more sampling within these classes would be required to determine if there is truly a consistent difference in vegetation communities between the classes. These two classes within the Fen and Wet Meadow ecological system were merged and treated as a single Fen and Wet Meadow class for the accuracy assessment of the land cover map.

Example photos of the Fen and Wet Meadow class (Class #'s 23 and 24)

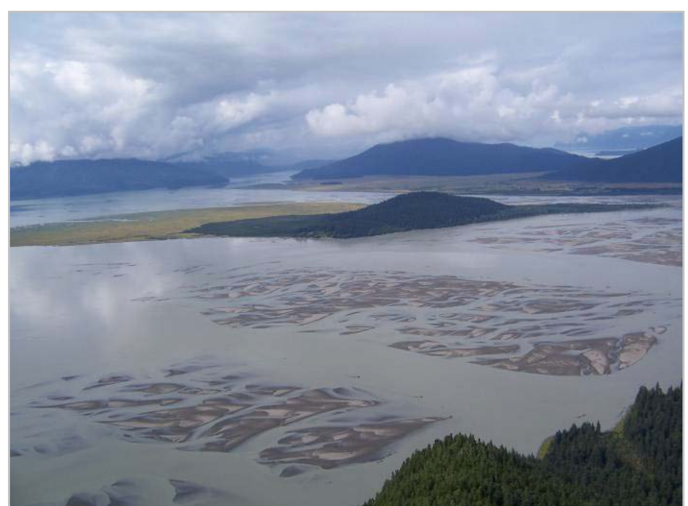
<u>Class 25. Mesic Herbaceous Meadow</u>.

This class combines the Alaskan Pacific Maritime Mesic Herbaceous Meadow and the Alaska Sub-boreal and Maritime Alpine Mesic Herbaceous Meadow of the Alaska Ecological Classification scheme (NatureServe 2008). No sites were visited in either of these classes during the field sampling although several areas matching the class descriptions were observed from a distance and locations were noted on field maps. The extent of the sites was either too small to sample, or the location of the sites were in areas that could not be visited within the guidelines of the helicopter safety plan. During the image processing portion of the project, a few unlabeled spectral classes intersected with these areas noted on the field maps and were therefore mapped into this class. These spectral classes were distributed throughout the image at a variety of elevations, and the species composition described for both of these classes is similar. These were the primary reasons for combining the Mesic Herbaceous and Alpine Mesic Herbaceous classes of the Alaska Ecological Classification scheme. Common species observed included *Calamagrostis canadensis*, *Chamerion angustifolium*, *Veratrum viride, Athyrium filix-femina*, or *Heracleum maximum.* This type was most often observed interspersed with the Tall Shrub Other class especially at higher elevations, and in avalanche slopes at all elevations.
(No example photos available for Mesic Herbaceous Meadow.)

COASTAL CLASSES

<u>Classes 31 and 32. Intertidal Mudflats (Non-vegetated and Sparsely Vegetated).</u>

This class represents exposed mud-flats of the Stikine River delta that are subject to daily flooding by tidal action. Two general groupings of spectral signatures were observed within this class which appeared to coincide with the presence or non-presence of sparse vegetation, so these were split out into separate classes in the final map. The species of marine vegetation observed in these sites was largely unknown. Much of the vegetation appeared to be algae, but some sites included small scattered clumps of what appeared to be *Puccinellia*. Only three sparsely vegetated sites and one non-vegetated site were visited in the field to very this, so any formal application of the final land cover map should combine these classes into a single Intertidal Mudflat class. It is unknown whether these vegetated areas are relatively stable or if they shift over time as tides and deposition rates reshape the delta. If they are somewhat stable, then this class split may be of interest if the distribution of shorebird or waterfowl usage across the Delta is ever examined in the future.



Example photos of Intertidal Flat – Non-vegetated class.

Example photos of Intertidal Flat – Sparsely vegetated class.

Classes 33 and 34. Tidal Salt and Brackish Marsh (Lower and Upper).

(*from NatureServe 2008, Temperate Pacific Tidal Salt and Brackish Marsh*) "[Tidal salt and brackish marshes]… are primarily associated with estuaries or coastal lagoons. Salt marshes are limited to bays and behind sand spits or other locations protected from wave action. Typically these areas form with a mixture of inputs from freshwater sources into coastal saltwater, so they commonly co-occur with brackish marshes. This is a small-patch system, confined to specific environments defined by ranges of salinity, tidal inundation regime, and soil texture. Patches usually occur as zonal mosaics of multiple communities. They vary in location and abundance with daily and seasonal dynamics of freshwater input from inland balanced against evaporation and tidal flooding of saltwater… In Alaska, tidal marshes are often dominated by near-monotypic stands of *Carex lyngbyei*, while the frequently inundated lower salt marshes are often dominated by *Eleocharis palustris* or *Puccinellia* spp."

Project specific comments:
Tidal salt and brackish marshes were found in large expanses on the outer edges of the large islands within the Stikine River delta and in smaller patches and narrow bands in many of the other smaller bays along the coastline within the project area. An attempt was made to map both the upper tidal salt and brackish marshes (class #34), dominated by nearly pure stands of *Caryx lyngbei*, and the lower tidal salt marshes (class #33), where *Puccinellia* spp., mudflat, and more open water were interspersed with *Caryx lyngbei*. The upper marshes were far more common and covered large expanses of the delta. The lower marshes were much more limited in size, often forming only a thin band along the outer edges of the upper marshes, and in many areas the upper marshes transitioned directly into the intertidal mud-flats.

Example photos of Lower Tidal Salt and Brackish Marsh class (Class #33).

Example photos of Upper Tidal Salt and Brackish Marsh class (Class #34).

Classes 35 and 36. Coastal Meadow and Slough Levee.
(*from NatureServe 2008, Alaskan Pacific Maritime Coastal Meadow and Slough-Levee)* "This ecological system includes moist and wet meadows associated with delta deposits, uplifted marshes, or beach deposits. These meadows occur inland of tidal marshes and are also common along sloughs and levees. Meadows are dominated by a wide variety of graminoids and forbs, including *Deschampsia beringensis, Festuca rubra, Argentina egedii (= Potentilla egedii), Lathyrus japonicus var. maritimus, Castilleja* spp., *Heracleum maximum, Parnassia palustris, Lupinus nootkatensis, Achillea millefolium var. borealis (= Achillea borealis), Angelica lucida*, and *Carex mackenziei*. *Leymus mollis* and *Lupinus nootkatensis* are common on levees, and *Carex lyngbyei* often dominates in sloughs and wet depressions."

Project specific comments:
This class formed large expanses on the Sergief and Farm Islands in the Stikine River delta and was also found in smaller patches in some of the smaller bays and inlets along the coast. The coastal meadows were very species-rich, diverse communities compared to any other class in the project area. The long, winding sloughs often led to small, brackish marshes containing bulrush (*Scirpus* spp. and/or *Schoenoplectus* spp.?) and other emergents. These small brackish marshes were far too small (5-10 meters wide) to map with the Landsat imagery. There were two very distinct spectral classes within this ecological system that were mapped into separate classes, Coastal Meadow and Slough Levee (CMSL) 1 and 2 (classes 35 and 36, respectively). Based on initial field observations, it was theorized that CMSL1 represented lower areas with a higher percentage of slough levees and, therefore, higher percentages of Carex lyngbeii and forbs such as Lupinus nootkatensis. CMSL2 was theorized to represent drier areas with a wide variety of forbs and greater concentrations of *Deschampsia* and *Calamagrostis*. Fieldsites were labeled into CMSL1 and CMSL2 based on these rough guidelines, but the landcover map was defined primarily on the spectral characteristics in the Landsat image. The error matrix reveals that there is confusion between these two spectral sub-classes when they are labeled in this manner. This indicates that further ground level sampling in the future may be needed to better understand the vegetation compositions of these two spectral groupings within the CMSL system.

Example photos of Coastal Meadow and Slough Levee class (Class #35).

Example photos of Coastal Meadow and Slough Levee class (Class #36).

SPARSELY VEGETATED AND BARE CLASSES

Class 41. Sparsely Vegetated - Riverine.

This class represents areas with at least 50% or more exposed soil or rock and more than 10% vegetation found within the flood plains of the major rivers within the project area and along river beds at higher elevations. The class represents sparsely vegetated gravel bars and sandbars along the major rivers, and sparsely vegetated rocky and gravelly riverbeds and streambeds at higher elevation. The class most often represents a mix of Alnus viridis and rock, gravel, sand, or mud, although many other herbaceous species are often present.

Example photos of Sparsely Vegetated - Riverine class (Class #41).

Class 42. Sparsely Vegetated – Other.

This class represents areas with at least 50% or more exposed soil or rock and more than 10% vegetation found outside of the flood plains of the major rivers within the project area. The class most often represents sparsely vegetated exposed bedrock at high elevations, on exceedingly steep slopes, and coastal rocky outcrops, or sparsely vegetated rocky areas within avalanche zones. There was significant spectral confusion between this class and the Sparsely Vegetated – Riverine class (class #41). Pixels of this class that fell within the floodplains of the major rivers within the project area were manually edited into the Sparsely Vegetated – Riverine class.

Example photos of Sparsely Vegetated - Other class (Class #42).

Class 43. Bare – Riverine.

This class represents areas of exposed soil or rock and less than 10% vegetation found within the flood plains of the major rivers within the project area. The class represents gravel bars and sandbars along the major rivers, and rocky and gravelly riverbeds and streambeds at higher elevations. Where the Stikine River enters the Stikine River delta, the demarcation between the Bare – Riverine class and the Intertidal Flat class (class #31) was manually edited. There is no spectral separation between these classes. The image processor looked for the island furthest toward the delta where the Sparsely Vegetated – Riverine class was still present. Exposed islands and mud beyond this point were edited to the Intertidal Flat class.

Example photos of Bare - Riverine class (Class #43)

Class 44. Bare – Other.

This class represents areas of exposed soil or rock and less than 10% vegetation found outside the flood plains of the major rivers within the project area. The class represents exposed bedrock, scree, or rocky areas at high elevations, on exceedingly steep slopes, coastal rocky outcrops, and rocky areas within avalanche zones.

No sample photos. Field sites in this class were not sampled because most areas in this class fall above the 2000' elevation limit of the project area, and the class can be mapped very reliably from on-screen image interpretation.

WATER CLASSES

These classes represent areas with greater than 50% water and less than 20% emergent, floating or slightly submerged aquatic vegetation.

Classes 51, 52, and 53. Clear Water, Turbid Water and Saltwater (respectively).

The separation between these classes was based off of the image processors interpretation of spectral differences within the satellite image and do not represent any specific, measured attribute such as turbidity or salinity. Turbid water generally represents the waters of the major, glacier fed rivers and lakes within project area. Occasionally, very shallow ponds, lakes and rivers where the substrate is visible through clear water may, spectrally, fall into the turbid water class. Also, mixed pixels of turbid water and conifer forest, and shadowed turbid water pixels along the major rivers would often confuse with the spectral classes associated with clear water.

OTHER CLASSES

Class 61. Terrain or Cloud Shadow.

This class represents dark, shadowed areas within the image that did not contain enough spectral information to define a vegetation class. They are most often spectrally confused with the clear water and conifer forest classes. Terrain shadow areas were identified using a shaded relief image that was created from the DEM layer, using the solar azimuth and solar angle information from within the header file of the Landsat image. Additional on-screen editing was required for many areas where the DEMs and Landsat image were not adequately georeferenced.

Class 62. Clouds.

This class represents areas covered by clouds in the satellite image. Most clouds in the Landsat image were associated with the highest mountains and glaciers and were not included in the <2000 ft. elevation project area defined at the onset of the project.

Class 63. Flooded Forest and Dead Trees.

This class represents a unique area of dead or dying, flooded forest and shrubland. The area, directly adjacent to the east of field site #149, was spectrally different that any other areas in the image and did not accurately fall within any of the other vegetated classes defined within the project area. It appeared that the area was most likely flooded by beavers.

Appendix B. Stikine Land Cover Accuracy Assessment Error Matrices

Table B1. Stikine Landcover Map - Error Matrix using fieldsites withheld for Accuracy Assessment

Class # and name	2. Treed Bog / Poor Fen	5. Deciduous Forest	7. Mixed Conifer For.	8. Sitka Spruce For.	9. Hemlock Forest	11. Tall Shrub Swamp - Fen	12. Tall Shrub - Other	13. Tall Shrub Swamp - River.	16. Dw. Shrub Sphag. Peatland	22. Emergent Veg.	23. Fen and Wet Meadow	34. Tidal Salt & Brackish Marsh	35. Coastal Meadow & Slough Levee 1	36. Coastal Meadow & Slough Levee 2	42. Sparsely Vegetated - Other	Total	User's Accuracy
2. Treed Bog / Poor Fen	**1**															1	100.0
5. Deciduous Forest		**8**														8	100.0
7. Mixed Conifer For.			**11**													11	100.0
8. Sitka Spruce For.			1	**6**												7	85.7
9. Hemlock Forest			1		**15**											16	93.8
11. Tall Shrub Swamp - Fen						**3**		1								4	75.0
12. Tall Shrub - Other							**11**									11	100.0
13. Tall Shrub Swamp - River.		1						**6**								7	85.7
16. Dw. Shrub Sphag. Peatland											1					1	0.0
22. Emergent Veg.										**5**	1					6	83.3
23. Fen and Wet Meadow						1				1	**2**					4	50.0
34. Tidal Salt & Brackish Marsh													1			1	0.0
35. Coastal Meadow & Slough Levee 1													**2**	2		4	50.0
36. Coastal Meadow & Slough Levee 2														**1**		1	100.0
42. Sparsely Vegetated - Other							1									1	0.0
Total	1	9	13	6	15	4	12	7	0	6	4	0	3	3	0	**83**	
Producer's Accuracy	100.0	88.9	84.6	100.0	100.0	75.0	91.7	85.7	-----	83.3	50.0	-----	66.7	33.3	-----		**85.5**

Total # Accuracy Assesment Sites: 83

Total # Correct Sites (*sum of major diagonal cells*): 71

Overall Accuracy: 85.5%

Table B2. Stikine Landcover Map - Training Site Error Matrix (using only training sites)

Class	2. Treed Bog / Poor Fen	3. Poorly Drained Conifer Woodland	4. Poorly Drained Conifer Forest	5. Deciduous Forest	6. Mixed Conifer and Deciduous Forest	7. Mixed Conifer Forest	8. Sitka Spruce Forest	9. Hemlock Forest	11. Tall Shrub Swamp - Fen Transition	12. Tall Shrub - Other	13. Tall Shrub Swamp - Riverine	16. Dwarf Shrub Sphagnum Peatland	21. Aquatic Bed	22. Emergent Veg.	23. Fen and Wet Meadow	31. Intertidal Flat - Non-vegetated	32. Intertidal Flat - Vegetated	33. Lower Tidal Salt and Brackish Marsh	34. Tidal Salt & Brackish Marsh	35. Coastal Meadow & Slough Levee 1	36. Coastal Meadow & Slough Levee 2	42. Sparsely Vegetated - Other	43. Bare - Riverine	51. Clear Water*	Total	User's Accuracy
2. Treed Bog / Poor Fen	**3**	1										1													5	60.0
3. Poorly Drained Conifer Woodland		**2**																							2	100.0
4. Poorly Drained Conifer Forest			**7**																						7	100.0
5. Deciduous Forest				**7**			1																		8	87.5
6. Mixed Conifer and Deciduous Forest					**1**						1														2	50.0
7. Mixed Conifer Forest			1			**12**	1	3																	17	70.6
8. Sitka Spruce Forest			1			2	**8**																		11	72.7
9. Hemlock Forest						2		**10**																	12	83.3
11. Tall Shrub Swamp - Fen Transition									**4**																4	100.0
12. Tall Shrub - Other						1		1		**12**															14	85.7
13. Tall Shrub Swamp - Riverine				1					1		**8**														10	80.0
16. Dwarf Shrub Sphagnum Peatland												**3**													3	100.0
21. Aquatic Bed													**3**												3	100.0
22. Emergent Veg.													1	**7**											8	87.5
23. Fen and Wet Meadow	1											1		1	**9**										12	75.0
31. Intertidal Flat - Non-vegetated																**1**									1	100.0
32. Intertidal Flat - Vegetated																	**3**								3	100.0
33. Lower Tidal Salt and Brackish Marsh																		**3**							3	100.0
34. Tidal Salt & Brackish Marsh																		1	**3**	1	1				6	50.0
35. Coastal Meadow & Slough Levee 1																				**4**	2				6	66.7
36. Coastal Meadow & Slough Levee 2																					**2**				2	100.0
42. Sparsely Vegetated - Other																						**3**			3	100.0
43. Bare - Riverine																							**1**		1	100.0
51. Clear Water*													1												1	0.0
Total	4	3	9	8	1	17	10	14	5	12	9	5	5	8	9	1	3	4	3	5	5	3	1	0	**144**	
Producer's Accuracy	75.0	66.7	77.8	87.5	100.0	70.6	80.0	71.4	80.0	100.0	88.9	60.0	60.0	87.5	100.0	100.0	100.0	75.0	100.0	80.0	40.0	100.0	100.0	----		**80.6**

** This row in the error matrix is a placeholder required for an error of omission in the Aquatic Bed reference column (it represents 1 Aquatic Bed field site that was incorrectly mapped as Clear Water). The 0% accuracy values for the Clear Water class are relatively meaningless because no Clear Water sites were collected for training nor accuracy assesment. Water was classified using on-screen visual interpretation of unsupervised spectral signatures. It is well established from previous landcover mapping projects in Alaska that have used these classification techniques that the water classes are mapped at far greater than 85% accuracy levels. It is assumed if an accuracy assessment of the water classes were performed that the class accuracies would be at least 85% accurate, and the overall map accuracy for the Stikine Project trainin sites (80.6%) would only increase.*

Total # Accuracy Assesment Sites: 144

Total # Correct Sites (*sum of major diagonal cells*): 116

Overall Accuracy: 80.6%

Table B3. Stikine Landcover Map - Combined Error Matrix (using all training sites and accuracy assessment sites)

Class	2. Treed Bog / Poor Fen	3. Poorly Drained Conifer Woodland	4. Poorly Drained Conifer Forest	5. Deciduous Forest	6. Mixed Conifer and Deciduous Forest	7. Mixed Conifer Forest	8. Sitka Spruce Forest	9. Hemlock Forest	11. Tall Shrub Swamp - Fen Transition	12. Tall Shrub - Other	13. Tall Shrub Swamp - Riverine	16. Dwarf Shrub Sphagnum Peatland	21. Aquatic Bed	22. Emergent Veg.	23. Fen and Wet Meadow	31. Intertidal Flat - Non-vegetated	32. Intertidal Flat - Vegetated	33. Lower Tidal Salt and Brackish Marsh	34. Tidal Salt & Brackish Marsh	35. Coastal Meadow & Slough Levee 1	36. Coastal Meadow & Slough Levee 2	42. Sparsely Vegetated - Other	43. Bare - Riverine	51. Clear Water*	Total	User's Accuracy
2. Treed Bog / Poor Fen	**4**	1										1													6	66.7
3. Poorly Drained Conifer Woodland		**2**																							2	100.0
4. Poorly Drained Conifer Forest			**7**																						7	100.0
5. Deciduous Forest				**15**			1																		16	93.8
6. Mixed Conifer and Deciduous Forest					**1**						1														2	50.0
7. Mixed Conifer Forest			1			**23**	1	3																	28	82.1
8. Sitka Spruce Forest			1			3	**14**																		18	77.8
9. Hemlock Forest						3		**25**																	28	89.3
11. Tall Shrub Swamp - Fen Transition									**7**		1														8	87.5
12. Tall Shrub - Other						1		1		**23**															25	92.0
13. Tall Shrub Swamp - Riverine				2					1		**14**														17	82.4
16. Dwarf Shrub Sphagnum Peatland												**3**			1										4	75.0
21. Aquatic Bed													**3**												3	100.0
22. Emergent Veg.													1	**12**	1										14	85.7
23. Fen and Wet Meadow	1								1			1		2	**11**										16	68.8
31. Intertidal Flat - Non-vegetated																**1**									1	100.0
32. Intertidal Flat - Vegetated																	**3**								3	100.0
33. Lower Tidal Salt and Brackish Marsh																		**3**							3	100.0
34. Tidal Salt & Brackish Marsh																		1	**3**	2	1				7	42.9
35. Coastal Meadow & Slough Levee 1																				**6**	4				10	60.0
36. Coastal Meadow & Slough Levee 2																					**3**				3	100.0
42. Sparsely Vegetated - Other										1												**3**			4	75.0
43. Bare - Riverine																							**1**		1	100.0
51. Clear Water*													1												1	0*
Total	5	3	9	17	1	30	16	29	9	24	16	5	5	14	13	1	3	4	3	8	8	3	1	0	**227**	
Producer's Accuracy	80.0	66.7	77.8	88.2	100.0	76.7	87.5	86.2	77.8	95.8	87.5	60.0	60.0	85.7	84.6	100.0	100.0	75.0	100.0	75.0	37.5	100.0	100.0	-----		**82.4%**

** This row in the error matrix is a placeholder required for an error of omission in the Aquatic Bed reference column (it represents 1 Aquatic Bed field site that was incorrectly mapped as Clear Water). The 0% accuracy values for the Clear Water class are relatively meaningless because no Clear Water sites were collected for training nor accuracy assesment. Water was classified using on-screen visual interpretation of unsupervised spectral signatures. It is well established from previous landcover mapping projects in Alaska that have used these classification techniques that the water classes are mapped at far greater than 85% accuracy levels. It is assumed if an accuracy assessment of the water classes were performed that the class accuracies would be at least 85% accurate, and the overall map accuracy for the Stikine Project (81.9%) would only increase.*

Total # Accuracy Assesment Sites: 227

Total # Correct Sites (*sum of major diagonal cells*): 187

Overall Accuracy: 82.4%

Appendix C. Notes on edits/modeling of draft landcover map in response to USFS Tongass National Forest staff comments.

Comments from the Wrangell Ranger District on Stikine Map draft product from Ducks Unlimited

Response and actions taken by DU to USFS comments are shown in blue text

Land Class Comments

1. There are some areas within the Stikine River floodplain where Tall Shrub – subalpine/avalanche have been classified where Tall Shrub – swamp/riverine class should be. Since these areas have very little slope and are not subalpine the Tall Shrub – swamp/riverine class is more appropriate. This misclassification was made several times in areas on Farm Island, near Twin Lakes, and Shakes Slough. Please correct. There is also an Alpine rock class in valley bottom up Andrews creek.

Wrote a model within Erdas to highlight all pixels that were < 10% slope, < 100 ft. elevation, and mapped as "Tall Shrub – Other/subalpine/avalanche" in the original landcover map. A few of these pixels were labeled correctly in the original draft map. This occurred where the DEMs were poorly georeferenced with the Landsat Image and steep slopes within avalanche chutes that reached down to the valley floor were incorrectly identified as slopes of <10% gradient. I left those pixels as Tall Shrub Other, but recoded all the other pixels identified by the model to the Tall Shrub – Riverine class. This fixed most areas, except for some of the floodplain areas further up the River in Canada where elevations near the valley bottom were >100ft. I re-applied the model in these areas further up-river, but revised the elevation ranges to correct the appropriate pixels in these areas.

Edited many scattered pixels of Alpine Rock and Alpine Sparse Veg to Riverine Rock and Riverine Sparse Veg in Andrews Creek and several other large drainages throughout the map.

2. There are parts of Shakes Glacier that are classified as Bare Riverine. This has probably occurred because the satellite imagery mistook the sediment within the glacier as riverbed deposits. Please correct.

Edited these areas from 'Bare – Riverine' to 'Ice/Snow/Glacier' class. Edited some additional areas within glaciers in the Canadian side of the project area also.

3. There are areas on Sergief Island that are classified as Lower Tidal Salt & Brackish Marsh where the area could be classified as intertidal Flat – sparsely vegetated. Please review and correct if needed.

This was the result of an incorrectly located training site (#299). This site was relocated while we were in the field because we had lost our GPS signal and couldn't navigate to the correct location on the tidal flats based on visual clues alone. We moved the site to the nearby edge of the Salt/Brackish Marsh where we could identify the location on both the ground and the fieldmap without using GPS. We had notes on the fieldmaps to show this relocation, but I failed to shift the site location in the fieldsite shapefile once we got back to the office. I've now corrected the site location in the fieldsite shapefile, and I've corrected the area in the final landcover raster map.

4. There is a hard distinction between Coastal Meadow & Slough Levee 1 & 2. For example when looking through the photos of the Coastal Meadow & Slough Levee 2 area east of Little Dry Island, it looks like it should be classified as Coastal Meadow & Slough Levee 1. Please review and correct if needed.

The distinction within the map between Coastal Meadow & Slough Levee 1 & 2 is based on relatively distinct spectral classes, and the map as originally delivered follows these spectral breaks very well in the Little Dry Island / Farm Island areas. Although the photos and field data for this area indicate that the area is relatively wet and has large amounts of sedges and E*riophorum*, the field data for site #260 (which falls within the area mapped as CMSL2) did estimate 30% cover of *Calamagrostis Canadensis* within the site. This relatively large percentage of grass fits well within the description of the CMSL2 class. As stated in the class descriptions in Appendix A, there needs to be a better field survey done in the areas mapped into these two sub-classes. The photos and more general helicopter based vegetation surveys did not lead me to a strong conclusion as to what vegetation assemblage(s) is/are responsible for the spectral distinction that is apparent in the Landsat image. I did not make any changes to the map in this area because the map should maintain the consistent spectral breaks displayed in the imagery, rather than being driven by the less consistent data seen in the field data and photos. Hopefully the field surveys that Rick Turner has conducted in the Stikine area can shed some additional light on this subject and help to identify vegetation species components leading to the spectral breaks observed in the imagery .

Photo Comments:

1. Photos 0825 actually shows up when identifying them through ArcMap as 0824_XXX. Please change.

Attributes are corrected.

2. The ArcMap does not show the actual locations of the photos 0825_287 and higher. Please reference where these photos are on the map. They seem to be in the photo folder but are missing on the map.

The GPS tracklogs for the last portion of the day on August 25 were corrupt. Two GPS's were running in the helicopter, but neither one collected a tracklog for that portion of the day. We were unable to link the photos beyond #287 with a GPS point. Some of the photos beyond #287 are associated with field sites. You will have to use the attributes within the site_photos_table to track which photos belong to each field site. The .mxd file in the project deliverables has a relate defined between the site_photo_table and the fieldsite feature class to help you with this.

3. When identifying each photo in the ArcMap program, each photo has a direction and heading associated with it. The direction/heading is NOT the direction and heading the photo is looking at. This is the direction/heading the helicopter was flying? If it is, I would take that information out. If someone who has never been to the area before is trying to reference where these photos are, it would be misleading. Either change the direction/heading to where the photos are actually pointing, or take out information.

You are correct, the direction/heading attributes represent the direction/heading of the helicopter. These attributes are automatically inserted into the attribute table for the photo points by the GPS Photolink software that we use to link the photos with the GPS tracklogs. I have removed these fields and several other blank or misleading fields from the attribute tables of the photo point feature layers

4. 0821_003, there is no photo.

This will be true for several photo points in the photo feature classes (shapefiles). These are photos that were blurry, had poor exposures, or inadvertent pictures (inside of helicopter, finger in front of lense, etc.). We deleted these photos to reduce the disk space required for storing photos, but did not have time to go back into each of the feature class files and delete the individual points for each of these photos. The photo point feature classes were created during the field work portion of the project. Each night, all photos were linked with GPS track logs and the photo feature class for that day was created. The photos were not fully reviewed until they were being used months later during the image processing phase of the project. The bad photos were deleted as they were encountered throughout the image processing phase, but the points were not always deleted from the feature classes/shapefiles.

Overall Comments:

1. Very impressive and overall quite accurate.
2. Great photography. It is exciting to have such wonderful photos of this area.
3. Question the accuracy of “shore pine” in Treed Bog and Poor Fen (shore pine) class name. Shore pine is infrequently encountered up the river (never in extensive hiking around Mallard slough by hunting forester, David Rak).

Valid point. I’ve removed that from the class name. If shore pine is present, then it most likely will be mapped by this class, but as described by the Ecological Systems Classification scheme it is not always present. The bog and poor fen areas described by this class can also be treeless.

All tables and figures in the final report have been updated to reflect the minor acreage changes in each landcover class that resulted from the edits made to address the Forest Service comments.